Contextual support of social engagement and reflection on the Web

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Contextual support of social engagement and reflection on the Web

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Preface

A research thesis is not only made by smart research questions, hypotheses, and research result. More often it is the little things that cannot be reported to a scientific audience that provide the bit of inspiration that pushes the process forward.

In the case of this thesis it was a summer afternoon I spent at the terrace of the Nivon house in Heerlen, where I stayed the first months after joining the *Open University of the Netherlands*. That afternoon I enjoyed the visit of my good friend Martin Schleicher and his family. After talking a bit about the early ideas of this research project, he connected my ideas with his experiences as a psychologist and told me a little anecdote about a very different and yet related type of feedback, compared to the approaches that are discussed later in this thesis. At that time he was working in a clinic with depressed people. He told me about people who are caught in a vicious cycle of (mis-) interpretations of social interaction, their deep distrust in the outer world, and social isolation. These people lack of positive feedback on their endeavours to manage their malady from their social environment. As a result they assume that whatever they do, nobody else is willing to give them support, and so they cut down their social relations. By the time these people end up with my friend, they are at a stage where they see any kind of social interaction as a misinvestment. So Martin told me about a little exercise they do with their patients in order to give them the feeling that already very small social interactions pay off: on afternoon walks the care workers sometimes make a little extension to the round to a nearby highway bridge. The actual exercise is to wave at the passing cars. Often to the surprise of the patients, many drivers or co-drivers in the cars wave back.

There is not much technology involved in this little anecdote, but a lot of learning. This anecdote is important for this thesis, because people recognise the big achievements of others and forget about the value of their own activities. Sometimes someone or something needs to "wave back" in order to help people to recognise their achievements. With my mind filled with applications of social software, I wondered, why it is that so much "social software" does not wave back.

For me there are many other people to wave at and to thank for their role in letting this thesis becoming reality.

First and foremost I wave at my promoters Prof. Dr. Rob Koper and Prof. Dr. Marcus Specht. I thank them for their great support throughout this research project. Through my involvement in TENCompetence, Rob's ideas, remarks, and comments

were helpful to elaborate the ideas presented in this thesis, and to see the bigger picture of this work. To Marcus special thanks for turning me back to *context* as the fundamental concept of our joint research in the group, and for his guiding advices through all the ups and downs of the past three years.

Secondly, I wave at my partner Marion R. Gruber for her understanding and feedback during the entire process. Backing my decision to move to the Netherlands, her constant and grounding feedback, and reminding me that there are other important things than work and computers. Her effort was a critical success factor for this work.

Lynne Chisholm and Helmut Fennes at the Institute of Educational Sciences at the University of Innsbruck I thank for pointing me at the field of non-formal and informal learning in lifelong learning. The last year at the Institute working with them helped to refocus on the relations of technology and education beyond formal e-learning and VLEs.

Jocelyn Manderveld of the Surf Foundation not only for inviting me to the 10th Surf onderwijsdagen: connecting me to the Dutch community was as helpful as the lessons in the depth of the Dutch language and culture. Together with Ruud Lemmers, Louis Maessen, and Bas Krekels from Logica all official and inofficial TENCompetence meetings were great fun and proved that there is more than work to be done in the Netherlands.

Our colleagues from Bolton University Scott Wilson, Phil Beauvoir, Dai Griffiths, and Chris Kew, for the interesting perspectives and discussions of standards, learning design, widgets, the iPhone, and the Web2.0. Special thanks to Chris for promoting ReScope through the official TENCompetence communication channels, and to Scott and Dai for contributing to the TENCompetence Winter Schools.

For his great help at the TENCompetence Winter Schools I wave at Stephan Pröll. Without his training skills on the mountain these events wouldn't have been as great as they were – and I would have to spend much more time in organising and less time on my research.

Many thanks also to Moritz Stefaner, Ralf Klamma and Steve Wheeler for their input on Web2.0 in education. Particularly, Steve's suggestion to publish my work on tag clouds earlier speeded up the last bit of this project.

I wave at Stefanie Lindstaedt for the invitation to discuss interaction footprints and indicators at the KnowCenter in Graz; and Sandra Schaffert and Wolf Hilzensauer from Salzburg Research for promoting the ReScope tool among their project partners.

For their support on the team.sPod spin-off project I thank Dirk Börner and Jeroen Storm. This extension of team.sPace for the Apple iPhone did not make it into this thesis, but the work helped to develop a broader theoretical foundation of this work.

Very special thanks go to my fellow PhD students Marco Kalz, Hendrik Drachsler, and Tim de Jong for the fruitful discussions and the great time sharing the desks in the "apecage". Much of the work was influenced by this group, although it is not visible. This is also the case for Malik Koné and Tim Sodhi who stopped their endeavours too early. Further, I wave at the rest of the PhD group at CELSTEC, those who finished recently, those who just started their projects, and all in between. Being part of this group is a great experience I would not like to miss.

Special thanks to Mieke Haemers also for proof reading this thesis and also to Danny Kostons and Sibren Fetter for helping with the translation of the abstract of this thesis into reasonable Dutch. Futhermore, I thank Jeroen Berkhout for his support in finalising the cover design.

I remember Jo Boon for always having an open door and an open ear for my struggles in project organisation. I thank my current and former colleagues at OTEC/CELSTEC for the nice atmosphere in the department. It has always been motivating in the whole process. Not forgotten is the support in organising all the little things in administration and project organisation of the secretaries at CELSTEC, foremost Mieke Haemers and Sabine Maassen.

Of course, there are many more people I have to wave at for being part of the process: our partners of the TENCompetence project, the lecturers and the participants of the TENCompetence Winter Schools in Innsbruck, the team of the Grillhof Vill, our partners in the GRAPPLE project, and my fellows of the #axkit-dahut group.

Last but not least I thank my parents. Without their support, love and patience I would not have gone as far as I am today; and my sisters Angi and Janine, without their help in my other projects this thesis would have taken much longer.

Waving at others at the end of a long way seems a bit like farewell, but it can also mean *"hello"*.

Christian Glahn

Chapter I
General Introduction[1]

Recently a new type of software tools has become popular on the Internet. These applications mark the advent of the Web 2.0 (O'Reilly, 2005). The Web2.0 refers not only to a new type of tools but also implies a new culture of using the Internet. The Web 2.0 stands for web-based services that allow their users to create and manipulate resources; that support sharing these resources with other users; and that help to build networks of peer users within the scope of the services' functions. This type of services is also referred to as social software, of which some success stories of commercial systems gained wider public attention (e.g., MySpace, Facebook, Flickr, Twitter). Another aspect of the Web 2.0 is that services are no longer considered to be standalone, but that they can be integrated into higher level services. Internet jargon calls these higher level services "mash-ups". For the interested user it is now possible to create simple mash-ups that integrate several services with the help of open standards, lightweight programming interfaces, and community specifications.

The ability of connecting services into new applications attracts also the educational technology community. One track in the related discourse is related to personal learning environments (PLEs). Different to institutional learning management systems (LMS), PLEs are learner centred mash-ups of the learners' Web 2.0 services (Wilson, Liber, Johnson, Beauvoir, Sharples, & Milligan, 2006). A PLE allows learners to link their learning experiences beyond the institutional learning environment, and support connecting more casual learning with official curricula. This view emphasises the relevance of self-directed and incidental learning for personal learning. The idea of PLEs as mash-ups of Web 2.0 services is directly connected to the constructivist concepts of emergence and self-organisation (Von Glasersfeld, 1995). This mashing of learning experiences holds potential for supporting learning beyond the boundaries of educational institutions. The supported kind of learning leads to communities of practice and self-directed lifelong learning.

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1 This chapter is partly based on:
Glahn, C., Specht, M., & Koper, R. (2008e). Supporting Reflection in Informal Learning. In Proceedings of the ECTEL Doctoral Consortium '08. September, 17, 2008, Maastricht, The Netherlands.

The term "self-directed learning" is a very broad and unspecific term for identifying learners or a specific type of learning. Therefore, it is necessary to define the term and narrow it down according to the definition and the problem setting. Self-directed learning is described as a process, "... in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes." (Knowles, 1975, p. 18) Over the years, self-directed learning has been applied in many settings as an educational technique. Marsick & Watkins (2001) connect self-directed learning to informal and incidental learning, which is the primary type of learning for knowledge workers and participants of communities of practice. In the following chapters *self-directed learning* is used for referring to *the conscious and unconscious learning processes of autonomous practitioners* such as knowledge workers for example.

Self-directed or incidental learning depends on a person's ability to reflect on her or his actions. Therefore, reflection is a key factor for this kind of learning (Schön, 1983, 1987; Ertmer & Newby, 1996). Schön (1983, pp. 141-156) notes that reflection is part of a self-directed learning process, in which move-testing inquiry guides the practice of professionals. Through this kind of exploratory on-the-spot research practitioners analyse complex situations and validate practical hypotheses based on the information they gather throughout the process. Feedback is a crucial aspect for this type of inquiry, because it is used by learners to assess the effect of their actions regarding their effects. In formal learning settings, feedback is often given by some kind of learning facilitator (e.g. a teacher or a tutor); sometimes it is given by the peer community. Formal learning environments are already designed in a way that allows learners to get feedback on their actions in an easy way. For example, repeated tests help the learners to understand their strengths and weaknesses; predefined curricula support learners to assess their performance in relation to the expectations and goals defined by the curriculum.

In self-directed learning the conditions of formal education are not always met. One difference between the different types of learning lies in the degree of role distinction (learner-teacher) and pre-defined learning scenarios (curriculum) in a learning environment. Formal education can be characterised by clear role distinction and a predefined curriculum that is provided for the learners, whereas self-directed learning is learner centred that often lacks of predefined roles and relies on a limited or even no form of a curriculum. To the extreme this may lead to situations in which reflection and exploratory experiments are no longer recognized as parts of learning processes (Bjørnåvold, 2000). The consequences of self-directed learning for the learning process are twofold. On one hand the learners gain more freedom, while on the other hand the implicit responsiveness of formal learning environments is missing in these settings. This includes reduced "institutionalised" feedback given by teachers and trainers or even the absence of feedback.

This affects especially emerging professions (e.g. in ICT); domains with relatively low professional recognition (e.g. youth training); or have not developed a professional structure (e.g. art and cultural heritage mediation), in which informal and self-directed learning is of higher relevance for the development of job related competences due to the lack of formal vocational education and training (Cheetham & Chivers, 2005). The lack of formally organized learning is partly compensated by "communities of practice" (Lave & Wenger, 1991). In these communities practitioners exchange their experiences and develop joint solutions for practical problems. This enhances the repertoire of unique problems and solutions, which is crucial for developing solutions in new settings on-the-spot (Schön, 1983, p. 138). Furthermore, communities of practice contextualize knowledge and learning experiences in social practice. Thus, learning can be considered as the socialization process into the social practice of a community (Lave & Wenger, 1991).

Another area where the increased value of informal learning can be observed is related to the knowledge economy. The concept of the knowledge economy is grounded on the ability of each worker in an organisation to analyse existing information, to share the resulted knowledge with peers, and to develop appropriate strategies for improving the economical performance and success of the organisation. The so called "knowledge worker" is by definition in a continuous learning process that is directly linked to the needs and demands of the position that is held by the worker in the organisation (Steward, 1998). Again, communities of practice are important facilitators of the learning processes of knowledge workers, because traditional forms of formal and even non-formal education are not capable to meet the advanced and highly specialised learning needs of the knowledge worker. Good examples of knowledge workers can be found in research and development (Roos, Roos, Dragonetti, & Edvinsson, 1997), particularly in research focussed academia. Practitioners in research and development have a long tradition of developing their job related competences through self-directed learning actions and communities of practices within and across their institutional boundaries: while many of their learning endeavours are so highly specialised that it is actually the researchers who develop courses on the topics of their learning, rather than attending courses themselves.

For knowledge workers and practitioners within weakly structured or emerging professional environments, "self-directed learning" is a process, in which developing knowledge and competences are not separated from practice. This connectedness of learning and practice holds the danger that the practice is mainly focused, while the related learning process becomes unconscious.

With regard to autonomous learners, two aspects for supporting learning can be identified from the existing literature. Firstly, participation in a community of practice is needed for sharing knowledge and developing ideas, concepts, and solutions. This aspect requires involvement in community learning and in the knowledge sharing process. This active engagement with a community cannot be presumed and requires support. Secondly, reflection is a meta-cognitive activity that is crucial for the personal learning process. By reflecting, learners actively evaluate their learning processes and the related outcomes. This process is a conscious activity and therefore stimulating reflection is a counter activity to avoid the development of tacit knowledge. Within the scope of this thesis social interaction and reflection have to be considered as personal or communal activities of informal learning, for which concepts and knowledge structures cannot be predefined.

Internet technologies are used by communities of practice for connecting their members, which is improved by the Web2.0 services that provide a better integration of different tools and ease the communication within the community. In these contexts technology support is considered as tools for communication and for information management that are arranged to meet the needs and the contexts of a community (Wenger, White, John, & Rowe, 2005). With respect to the tools that are used in informal learning, Wenger, White, John, & Rowe (2005) argue that Web2.0 services play an increasing role for facilitating communication and information organisation between the peers of a community of practice. Furthermore, Web2.0 services allow the creation of enriched services by combining existing services through data exchange formats. This improved extensibility of services to the needs and contexts of a user or a community holds great potential for allowing further personalisation and contextualisation of services that support lifelong learning. The main novelty of PLEs for lifelong learning lies in the network perspective of these environments. In this sense allow the services that are connected in a PLE to connect learning networks across the boundaries of the individual communities (Koper et al., 2005). However, the related research is still in its early stages and the applications of social software reported in both the community of practice and the learning network contexts do not tackle the problem of raising attention to the learning processes that are part of the professional "artistry" (Schön, 1983) and professional competence development (Cheetham & Chivers, 2005). This thesis contributes to the discussion about the application of web2.0 technologies for supporting informal learning.

Attention, footprints, and indicators

From the perspective of move-testing inquiry – or as Schön (1993, p. 146) calls it: "move-testing experiments" – it is reasonable that reflection support should follow a cyclic principle of refinement and testing (Chapter 2). In this cycle learning is not understood as a cognitive activity, but as a dialogue between a learner and the environment. This dialogue is a dynamic process, in which both sides develop and influence each other (Schön, 1983). In order to take both the individual's and the environmental perspective into account, the existing models provided by Butler & Winne (1995) and Garries, Ahlers, & Driskel (2002) were combined and extended with the systemic model of context aware systems, which has been described by Zimmermann, Specht, & Lorenz (2005). The resulting "learning interaction cycle" describes learning as an interactive process in which the environment is *aware of* and *responsive to* the activities of a learner.

In unstructured environments, such awareness of the system can be achieved by observing the learners' actions within their environment. From the data collected by these observations, which can be as simple as mouse clicks on links on a web-page or tags that were assigned to resources, it is possible to deduce higher level information. One example for such information is "attention meta-data" (Najjar, Wolpers, & Duval, 2006). However, attention meta-data appears not always to be flexible and informative enough to achieve the required responsiveness for supporting learners. For this reason, a more flexible approach for generating such activity-based information has been proposed. This approach is based on the data aggregators (Dey, 2001), which can be arranged with respect to the learners' situation and progress on their learning path.

Therefore, it is assumed that user-generated meta-data helps to identify explicit and implicit interests of users, which can be used to stimulate reflection on their personal learning processes. This research has similarities to utilizing information about explicit and implicit interest of users to support their interaction with online information systems (Claypool, Le, Wased, & Brown, 2001). As such the research is closely related to the works in the area of attention meta-data (Najjar, Wolpers, & Duval, 2006), to user adaptive systems (Farzan & Brusilovsky, 2005), and to social awareness (Erickson, 2009; Erickson & Kellogg, 2003; Kreijns, 2004). The purpose of this work is to provide an integrating view for stimulating and supporting situated learning, that does not only reflect the temporal needs of learners but also allows adapting to the changing context of the learners. This implies that the learning process cannot be considered as a constant process, in which each response has always the similar effects. Instead, the learner's experiences are evolving, which changes the ways of interpretation of external responses on a learner's actions. This is a well known effect in workplace related competence development (Cheetham & Chivers, 2005).

Although there are examples for visualising interaction footprints for supporting self-regulated actions of learners in online environments, they are limited to a single context, because all users are assumed to interpret the presented information similarly. For this reason the concept of a smart indicator has been introduced. Such an indicator is defined as *a context aware indicator system, which dynamically aligns data sources, data aggregation, and data presentation to the current context of a learner* (Chapter 4). Therefore, a smart indicator can be considered as a context adaptive system.

Question of research

The objective of this research is to *explore* contextual dimensions for *learner support* in unstructured environments, in which no predefined curriculum and explicit educational guidance is available, and users might be at different stages on their learning course. The previous sections briefly introduced four concepts for supporting lifelong competence development: *self-directed learning, Web2.0, context, and interaction footprints*. These concepts are the cornerstones for the over arching research question of this thesis. Within this scope the particular interest of this thesis is phrased by the following question.

> *How to provide appropriate support strategies and use interaction footprints as a source of information that is suitable for stimulating engagement in social interaction and reflection of self-directed learners on the Web2.0?*

This question is loosely guided by Schön's (1983) notion, that today's professionals are confronted with a range of situations that are highly complex, uncertain, and dynamic. In these situations it is not always possible to apply deterministic and hard empirically grounded methods in ways as it is taught in schools or universities. In other words, professionals have to manage "messes" and make sense of these in order to provide services to their clients (Schön, 1983, p. 18). However, the related learning processes might be unconscious to the learner. Considering this, the question for research becomes: "how to support learners in unstructured and emerging environments to become aware of their self-directed learning processes while using Web2.0 tools?" In order to support learning under these conditions, prior research (Mory, 2003; Ley & Young, 2001) argued that feedback has to be appropriate to the context and meaningful to the learner. This suggests that responses should be contextualised to the learners' needs.

The approach for providing feedback that is discussed by this thesis is called *indicators.* Indicators are simplified representations of selected aspects of complex environments. Actors depend on indicators as contextual information for organising, orientating and navigating through complex environments (Butler & Winne, 1995). Contextual information on the learning process has been proven to support learning. This information stimulates the learners' engagement in and commitment to collaborating processes; it helps to raise awareness of and stimulates reflection about social dynamics (Erickson, 2009) and acquired competences (Kreijns, 2004); and it supports thoughtful behaviour in navigation and on learning paths. Despite the evidence on the role of indicators as providers of relevant information for the self-directed learning process, research has so far considered indicators only as context free or context neutral sources of information. Contrasting this perspective the term *support strategies* in the question for research implies that the type of indicator may change depending on the context of the learners.

The novel idea underlying the proposed contextualisation of indicators is that visualisation of interaction footprints alone can simulate social engagement and reflection if it is appropriate for the context of the learner. The contextualisation of indicators for visualising interaction footprints can be seen as a minimalist form of personalised feedback on the learning process. Instead of being dependent on explicit learning goals and a fundamental model of the knowledge domain, this thesis proposes a type feedback that uses observations the learners' past actions and situations.

These concepts and ideas of this thesis are tightly coupled with their application. The question about "how to provide ..." implies the relation of this research with the emerging practice of using Web2.0 technologies in education and learning. Therefore, the research question does not ask for the effectiveness and efficiency of the technology for supporting education and learning, but addresses the need for *exploring* the relation of contextual factors with the learning process and for *designing* solutions that utilize these contextual factors to support learners outside of formal educational settings.

Design research

The scope of the research question towards the design of solutions for supporting learning in non-educational environments contextualises the method approach of this thesis within design research. This contextualisation has implications on the research process and how to interpret the findings of the underlying research. This section discusses design research and relates this method to the content of this thesis.

Design research describes research approaches that study the effects of artificial tools and solutions in their intended real world context. The tools and solutions are analysed as *designed* products and services from the perspectives of the perspectives of stakeholders that are involved in the existing application settings of the products and services. This analysis is carried out in so called *design experiments* (Brown, 1992). For the research process it is necessary to remark that "design experiments are contextualised in [real world] settings, but with a focus on generalizing from those settings to guide the design process" (Collins, Joseph, & Bielaczyc, 2004, p. 21). Therefore, design research covers a class of qualitative approaches to research that are guided by formative processes of inquiry. In order to underline the differences between the qualitative inquiry of design research and laboratory experiments, the term "design study" is used in the following instead of "design experiment".

According to Edelson (2001) the related process includes the following phases.

1. The development of a theory.
2. The derivation of principles for design from the theory.
3. The translation of the principles into concrete designs.
4. The assessment of the designs to test whether they work as anticipated.

This process is then extended through "progressive refinement" (Collins, Joseph, & Bielaczyc, 2004), in which the design principles and the concrete design are revisited based on the results of the assessment outcomes. This refinement also influences the development of the theory. This notion of "theory" indicates also one of the major differences between design research and other types of research. From the perspective of design research, a "theory" is not necessarily fully specified or comprehensive, but it evolves with the design (Edelson, 2001; Kelly, 2004).

Edelson (2001) identifies three main types of theory that can be the result of a design research process: domain theories, design frameworks, and design methodology. Domain theories focus on the development of *descriptive* theories and models about the contexts for application of a design or the outcomes of its application. Design frameworks are *prescriptive* theories on educational models or technical architectures that are based on the *substantive design principles*. Design methodology refers to process theories that focus on the process of achieving appropriate outcomes using a design, on forms and conditions in which a design is applicable, or at social relations and social dynamics that influence the design. These theories develop and elaborate the *procedural design principles*.

In the educational domain, design research has been developed to address several issues that are central to the study of learning, among which the following are factors (Collins, Joseph, & Bielaczyc, 2004, p. 16).

- The need to address theoretical questions about the nature of learning in context.

- The need for approaches to the study of learning phenomena in the real world rather than the laboratory.
- The need to go beyond narrow measures of learning.
- The need to derive research findings from formative evaluation.

Although the design research is a tool for addressing these needs, the objective of generalizing yields some challenges that are related to the empirical methods and the process of theory testing of laboratory experiments. Kelly (2004) highlights that generalisation of design research results is not possible at the levels of actors, behaviours, and contexts, given to the qualitative approach of design testing that use often only one stetting with small samples and many uncontrolled variables (Kelly, 2004, p.120-121). Therefore, design research is not an approach to theory testing, but it is an approach to the development of useful and generalisable theories (Edelson, 2001) that focuses on the identification of necessary design principles and the creation of powerful hypotheses (Kelly, 2004).

For this thesis the design research approach was selected for three reasons. The first reason was that the underlying theories of cognitive psychology and the current state of research in the field of technology enhanced learning could not be combined to model sound and yet powerful experimental settings that would help to study the nature of supporting self-directed and incidental learning (Chapter 2). The second reason was that the concept of context puts some constraints in the design and the evaluation of learning supporting systems. Personal and inter-personal differences of context are involving a range of variables that cannot – and must not – be controlled during experimental studies in order to identify context related differences that are related to the incidental nature of this type of learning. The final reason is that there was no educational theory on the technological support for self-directed and incidental learning that is applicable for developing technical tools that can support these learning processes. The existing research analysed the application of software and online tools mainly as tools for communication or information management (Wenger, White, John, & Rowe, 2005), but not as tools particularly designed for supporting learning processes.

The design objective of this thesis is anchored at the levels of design frameworks and design methodology. At the level of design framework is the focus on the development of design principles for supporting engagement and reflection in self-directed and incidental learning, based on existing motivational models and on an architecture for context aware systems. At the level of design methodology is the focus on forms and conditions for supporting learning processes in highly unstructured environments. The social context is given in this thesis through the knowledge worker who uses Web2.0 tools for personal and collaborative tasks. The underlying structure and principles of using interaction footprints as a domain independent source for this kind of learning support can be (partially) transferred to other groups in equally unstructured settings, in which ICT tools are used for information management and communication in similar ways as used by the knowledge workers that are targeted by the design studies of this thesis.

Because of the design objectives, this thesis does not only include the successes of the design studies, but also takes a critical view on the pitfalls that were encountered during the experiment. Particularly, the participation and the use of the tools including start-up problems are of interest for identifying the underlying factors of online tools for supporting the self-directed and incidental learning process. This means that the learners choose the tools as they see them suit their personal benefit.

Structure of the thesis

This thesis documents the design research process of studying how indicators that are based on interaction footprints can support self-directed and incidental learning, and how contextual factors influence the effects of indicators in this process. The thesis has two parts. Part 1, *theories, use cases, a technical architecture*, combines the theoretical underpinnings and approaches of prior research with the initial design considerations for contextualised learning support. Part 2, *design studies*, targets the research questions that were raised by the theory as they are implemented in the design of indicator systems. This part reports on the results of design studies on context factors for learner support.

The first part starts with an analysis of the theoretical foundations of contextualised learning support for self-directed and incidental learning (Chapter 2). Chapter 2 elaborates the three theoretical pillars of this research. The chapter provides an overview on the theoretical foundations and models that were used in the other chapters. Within the design research process it defines the foundations of a theory, upon which the designs for supporting learning are based. Chapter 3 provides a first scenario of contextual learning support in self-directed learning processes; and uses a model of context aware information systems to analyse selected literature on the use of indicators for supporting learners in self-directed or informal learning. This analysis of the literature seeks for substantive design principles that can be applied in the initial design. The first part concludes with a study on the initial design of a system for contextual learner support (Chapter 4). This study embeds a context-adaptive indicator system in a group information portal of aggregated peer contributions. The study proposes a first contextualisation strategy for learners at different participation levels.

The second part focuses at two areas for supporting self-directed and incidental learning: *social interaction* and *personal information management*. Within these areas two aspects of learning support were the major interest of this research: *engagement* and *reflection*. Chapter 5 and Chapter 6 focus on the area of social interaction. Both chapters are based on the results of the initial design study. Chapter 5 analyses the contextual boundaries that were suggested for the context adaptation strategy of Chapter 4. Two activity indicators are compared with regard to their effect on the engagement in a peer information portal of learners at different levels of participation. Chapter 6 analyses how tags were used actively (while bookmarking or blogging) and passively (while accessing links and blogs) by the participants of the first study. The chapter addresses the question if footprints of active resource tagging and the reading of tagged resources can be used to infer different kinds of topic related interests for learners across different levels of participation. Chapter 7 focuses at a contextual design of a tag cloud for supporting reflection on the personal bookmarking behaviour in a social bookmarking system. Chapter 7 concerns the design and evaluation of a tag cloud as an indicator for reflection support and discusses the findings of initial experiences using this indicator. The evaluation analyses if context based design considerations can be confirmed by the reflections reported by the users of the tag cloud. The final chapter (Chapter 8) discusses the lessons learned from the results of the three studies with respect to the research question.

Part I

Theories, Use Cases, and Technical Architecture

Chapter 2
Three Pillars for Research[1]

This chapter discusses the theoretical background of this thesis. The chapter starts with situating the research in the larger context of lifelong competence development and learning in the professions. Within this scope the focus on self-directed and incidental learning is contrasted with other types of education and learning. Based on these foundations the chapter elaborates the three theoretical pillars for this research: situated learning, feedback, and information visualisation. These pillars are contextualising the work in this thesis and provide a conceptual framework that has been applied for the system design and the evaluation of the concepts.

Every research needs some scientific backing and a theoretical model to build upon. This chapter covers the key concepts underlying contextualised learning support for self-directed learners. The topic of this thesis is interdisciplinary, and so is the theoretical background. Therefore, the scope of this chapter scratches the domains of continuing vocational education and training (CVET), of self-regulated and self-directed learning, and of information visualisation. Each domain has its own relation to technology and to technology enhanced learning. Although there are several publications for each of these

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1 This chapter is based on:
Glahn, C., Specht, M., & Koper, R. (2007). Smart indicators on learning interactions. In E. Duval, R. Klamma, M. Wolpers (Eds.), *Creating New Learning Experiences on a Global Scale* (pp. 56-70). Berlin, Heidelberg: Springer.
Glahn, C., Specht, M., & Koper, R. (2008a). Visualisation of interaction footprints for engagement and motivation in online communities – results of first interviews. In M. Kalz, R. Koper, V. Hornung-Prähauser, & M. Luckmann (Eds.), *Proceedings of the 1st Workshop on Technology Support for Self-Organized Learners* (pp. 29-43). June, 2-3, 2008, Salzburg, Austria. Available at http://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-349/glahn.pdf
Glahn, C., Specht, M., & Koper, R. (2008b). Implications of writing, reading, and tagging on the web for reflection support in informal learning. In M. Specht & P. Dillenbourg (Eds.), *Times of convergence, technologies across learning contexts* (pp. 110-121). Berlin, Heidelberg: Springer.
Glahn, C., Specht, M., & Koper, R. (2008c). Reflecting on web-readings with tag clouds. Paper presented at the *Computer-based Knowledge & Skill Assessment and Feedback in Learning Settings* (CAF). Special track at the 11th International Conference on Interactive Computer aided Learning (ICL 2008), Villach, Austria.
Glahn, C., Specht, M., & Koper, R. (2008d). Smart indicators to support the learning interaction cycle. *International Journal for Continuing Engineering Education and Life-Long Learning*, 18 (1), 98-117.
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Glahn, C., Specht, M., & Koper, R. (submitted). A tag cloud for the reflective self-directed learner. *Journal of Computer Assisted Learning*.

domains, this chapter will not provide a comprehensive overview to all of them. Instead, selected perspectives of the different domains are integrated into a theoretical framework. This framework serves as the foundation for the empirical and technical concepts that are studied throughout this thesis.

The term *learning* has been used with various meanings in different contexts. Marsick & Watkins (2001) locate informal learning close to formal education. While formal learning is institutionally sponsored and highly structured, informal learning is less structured but it is guided by learning goals. Additionally the authors distinguish *incidental learning*, which is defined as the by-product of other activities. This last type of learning is almost always unconscious to the learners. Livingstone (2001) provides a definition based on the level of control and on knowledge structures. The control on the learning process can be either with the learners or with the trainers. Knowledge structures can be classified on a continuum between pre-structured and situational. Following this schema, formal education is defined by a high degree of teacher control and pre-structured knowledge. Non-formal learning is given, if the knowledge is pre-structured but the learners are mostly in control over the learning process. Informal learning or informal education is defined by a high degree of teacher control and a situational knowledge structure. If the knowledge structure is situational and learners are in control of their learning processes, Livingstone speaks of *self-directed* or *collective* learning. *Incidental learning* in Marsick & Watkins' (2001) terminology is according to Livingstone (2001) a special type of self-directed learning, which the author calls *tacit learning*.

Given this categorisation, this research focuses mainly on "self-directed learning" including forms of *tacit learning*. This type of learning is a key factor for individual competence development in the context of CVET (Chisholm, Spannring, & Mitterhofer, 2007; Elkær, Høyrup, & Pedersen, 2007). Traditional forms of competence development in the professions are often based on teacher centred approaches as well as on explicit concepts, ethics, and processes (Cheetham & Chivers, 2005; Eraut, 1997). Such approaches to competence development cover by no means all the problems, challenges, and tasks of the daily working routine. Many competences have to be learned through practice. On the one hand, the knowledge and competences that are developed that way are of great relevance for effective professional performance (Gherardi, 2006). On the other hand, the daily routine masks the learning processes that are involved in the professional practice (Schön, 1983). As a result, many individuals are unaware of their informally developed competences or have difficulties to value these competences. This unawareness hinders them regarding their self-esteem, productivity, and employability (Evans, Kersh, & Kontianen, 1996; Preißer, 2005; Gerzer-Sass, 2005). Using digital tools in non-formal and self-directed learning have been used to overcome the barrier of unconscious competences (Ajello & Belardi, 2005). However, the full potential has yet to be explored. With this respect research challenges were identified in the areas of pedagogical models for learning beyond formal learning environments, knowledge management and sharing, and task related support (Koper & Specht, 2007).

Within the scope of supporting self-directed learners it is the primary goal of this research to stimulate the learners' engagement and reflection about their learning processes and retain the self-directed nature of their learning course. The secondary goal is to find a solution to learning support that is independent from specific knowledge about the knowledge domain and the learning goals of the learners. Taking both goals together learner support in self-directed learning has to deal with some uncertainty regarding the learning goals, the learning content, and the learning process.

One approach to these problems is provided by recommendation systems (Claypool et al., 1999; Drachsler, Hummel, & Koper, 2009). Although recommendation systems approach the problem of uncertainty, these systems try to infer possible learning goals from the learners' activity and try to suggest possible pathways for the learning process.

An alternative approach to this problem is to provide feedback on the past learning activities. Feedback is defined as "any communication or procedure given to inform a learner of the accuracy of a response" (Mory, 2003, p. 745). Such a response can be considered as any type of learner action. With respect to technology enhanced learning feedback is also considered as "any message or display that the computer presents to the learner after a response" (Mory, 2003, p. 745). From a constructivist perspective, feedback "would occur in the form of the interactions between the learner and the activity of solving real-world problems. Rather than providing predetermined instructional sequences, feedback can be used as a coaching mechanism that analyses strategies used to solve these problems" (Mory, 2003, p. 772). Although most approaches to provide feedback emphasize instructional settings that require explicit knowledge about the learning domain and the learning goals (Mory, 2003), this restriction is not a requirement for feedback from the constructivists' point of view. In order to clarify this, feedback is defined for the purpose of this chapter as *any message or display of an interactive system presented to a learner that is based on the analysis of the learner's actions*. The type of messages given by recommendation systems clearly falls under this definition, but the definition also opens space for a type of feedback that does not include direct recommendations of suitable actions. This feedback uses the outcomes of the analysis of the learner's actions as an instrument for *coaching*. This kind of feedback does not offer an interpretation of the analysis but allows the learners to develop a meaningful understanding of the provided information in relation to their actions.

One form of displaying analysis results is through graphical presentation. Graphs, charts, and diagrams are commonly used to present statistical data. Using data visualisations also allows abstracting from the actual content and the actual activities. If a data visualisation presents the results of an activity analysis of an ongoing process, this visualisation is called an *indicator*. Indicators are not uncommon in educational systems, but most of them are used for teaching support rather than for coaching the learners. In those cases where indicators are available commonly only one indicator is used for all learners.

Eraut et al. (2004) note that inadequate feedback can weaken motivation and reduce commitment to the learning process; and that with regard to learning in the professional workplace, learning factors appear to be related to context factors that seem to influence the individual learning experiences. This means that learners in different contexts and situations may have different understandings of feedback – even if they receive similar responses. Therefore, it appears to be useful to personalise the feedback according to the context of a learner in order to provide adequate responses on learner actions.

These considerations lead to the three pillars in theory of this research. The first pillar is the field of self-directed learning of adults. These ideas are closely related to the research on CVET. The second pillar is related to research about *motivation* and *feedback*. The related research focuses on the relations between learner performance and related external responses. The third pillar focuses on data and information visualisation and how such visualisations can be used for learner support. The general findings in the field of CVET indicate that it is also required to contextualize feedback meaningfully to the situation of a learner. Therefore, the intersection between the first and the second pillar can be located in the area of *situated learning* and *situated cognition*. The concept of indicators is located in the intersection of the second pillar and the third pillar. The areas of CVET and information visualisation are connected through the broad term *learner support*. This means that information visualisation is mainly used to support learning processes by visualising complex structures, for example in training simulations, or to visualise social processes and dynamics. Figure 2.1 visualises the relations of the three pillars.

The three pillars leave a white space in their common intersection. This intersection of the three pillars can be titled as "indicators for learner support in situated learning" or as "contextualised indicators for learner support". In Figure 2.1 this space is intentionally left blank, because no research addressed this area, yet.

For the view on the three pillars, the reader has to bear in mind that the objective of this chapter is to develop the grounding for designing technical solutions that support self-directed learning. Therefore, this chapter focuses on selected theories and concepts that can be used for this purpose. This reasoning implies that this chapter covers theories that are practical enough to define design and evaluation criteria for technical solutions. In order to show this relevance for the practical applications in technology enhanced learning, this chapter relates the theories to relevant concepts of information technology research.

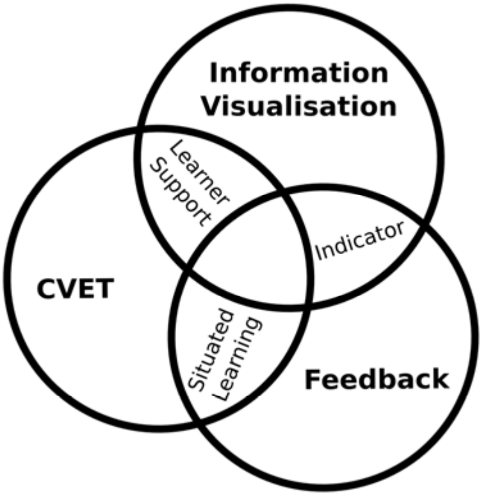

Figure 2.1: Relations of the three pillars of research

The following sections develop the theoretical framework for the following chapters. The sections of this chapter present the three pillars from the perspective of the intersections that lead towards the space that is addressed by this work. First, this chapter discusses "situated learning" from the perspective of contextualising learning experiences. This section addresses educational variables of contextualisation. This is the "situated learning pillar" of this research. After that, the focus is on models for understanding and designing feedback to stimulate and support self-directed learning. This is the "indicator feedback pillar". The third section analyses different theoretical concepts of information visualisation for learner support. The section analyses different perspectives on analysing and presenting learner actions to the learners to stimulate social participation and learning. This will provide the "information visualisation pillar". Finally, this chapter arranges the three pillars and formulates the research agenda for this thesis.

The Situated Learning Pillar

Lave & Wenger (1991) have introduced the terms "situated learning" and "legitimate peripheral participation". Both terms reflect the social dimension of learning. Situated learning emphasizes that learning is always embedded and contextualized by the social practices of the social community, in which the learning takes place. "Legitimate peripheral participation" (Lave & Wenger, 1991) refers to the process of a person becoming a fully participating and accepted member of a community through participating to this community. Therefore, learning is defined as the process of "understanding in practice" that is embedded in participating in day-to-day activities (Lave, 1993; Wenger, 1998). In such settings, learning is influenced by cognition, action, and context, which cannot be separated from each other and equally affect the learning process (Collins, Brown, & Newman, 1989; Lave, 1993). Lave & Wenger (1991) use the term context to describe both physical and social settings in which people act.

Situated learning therefore covers three fundamental aspects: understanding, social participation, and context. This means that learning depends on the context in which it takes place. Intuitively, this can be translated into the question: what are the constitutive relationships between persons and the contexts in which they act? This question addresses the relation of cognition, action, and context. The related research highlights that the learning context is based on the relationships between local practices that contextualize the ways people act together, both in and across contexts. From this perspective the notion of *context* is twofold. On the one hand, context defines possible activities. On the other hand, context is defined through the activities of people. This means that learning cannot be reduced to a set of "contextual learning events", but needs tight coupling to the social practices in which learning is situated.

The coupling of social practices, learning, and context is linked by Wenger (1998, 2007) to the concepts of "identity" and "meaning". Identity refers to self identity, including knowledge and skills, the personal history, and the role in a social community. Meaning refers to the personal model of the world, which is used for physical and social orientation, sense making, and navigation. Both concepts are part of "socio-cultural production" (Lave, 1993) and are actively constructed by the learners. This construction process is contextualized by six dimensions (Lave, 1993), which can be summarized as following.

1. Process
2. Group or peers
3. Situation and event
4. Participation
5. Concept
6. Organization or culture (the contextual "world" of the learners)

Wenger, White, John, & Rowe (2005) analyse the role of technology for communities of practice. This analysis mainly focused on social software that is used by online communities of practice. While this analysis focused mainly on integrated (commercial) platforms, a newer study of the authors takes a wider perspective on social software by analysing the use of tools and tool sets in terms of the Web2.0 (Wenger, White, John, & Rowe, 2005). The authors identify thirteen fundamental elements in which technology can affect the success of a community of practice – and thus influences the learning processes within (Wenger, White, John, & Rowe, 2005, p. 45). These elements have contextual functions within the collaborative learning process. Figure 2.2 shows the relation between Lave's (1993) contextual dimension and Wenger's (1998) context factors.

Lave, 1993 → Wenger, 1998 ↓#	Process	Peers	Event	Partici-pation	Concept	World
Presence		X	X	X		
Rhythm	X		X			
Interaction		X		X		
Involvement				X		
Value		X			X	X
Connections		X			X	X
Personal Identity				X		
Communal Identity		X		X		
Relations		X				
Boundaries		X		X		X
Integration	X	X				
Community building	X	X		X		

Figure 2.2: Context dimensions and context factors

This mapping allows identifying the types of possible interpretations of the learning processes that can be expected for each context dimension. For example if the participation dimension is focused as the primary context dimension, it can be expected that learners relate meaningful learning experiences to the following factors: *presence*, *interaction*, *involvement*, *personal identity*, *communal identity*, *boundaries*, and *community building*.

Recently, Zimmermann, Lorenz, & Oppermann (2007) provided an analysis of sensor information regarding their technical dimensions. These dimensions allow the design of different personalisation and adaptation strategies on the grounds of sensor information. This categorisation can be considered as a technological approach to the high-level contextual dimensions of Lave (1993) and Wenger (1998).

The technical approach to context aware systems of Zimmermann, Lorenz, & Oppermann (2007) is based on the context definition given by Dey (2001). Dey (2001) defines context as any information that can be used to characterise the situation of an entity. Typically this information falls into one of the following five categories:

"individuality", "activity", "location", "time", and "relations" (Zimmermann, Lorenz, & Oppermann, 2007). These dimensions can be used to design sensor networks. The sensors of these networks can then provide data from which the situation of an entity can be inferred relative to each of the dimensions. The sensor data also helps to detect changes of the context of entity or to identify overlapping contexts between different entities.

The Indicator-Feedback Pillar

Both awareness and reflection are needed for learning processes and competence development. Particularly in unstructured and unguided environments, like workplaces or online communities, a person's ability to reflect on his or her actions is a factor for competence development (Schön, 1983, 1987). Schön (1983) distinguishes two variations of reflection that are relevant to learning: reflection on action and reflection in action. In both cases the learner creates a relation between past experiences and a situation. The main difference of the two kinds of reflections is the time when the reflection takes place in relation to the actual action. *Reflection on action* refers to those activities in which the "learner" reflects on past actions. This implies that the action that is focused by the reflection has already been completed and cannot be changed by taking insights resulting from the reflection into account. Compared to this perspective, *reflection in action* takes a different perspective on reflection and refers to those cognitive processes that are involved in the application of knowledge and experiences for assessing and controlling an ongoing task. In this case, reflection is directly related to and intertwined with the action in progress.

The key aspect of Schön's theory is the connection between action and reflection, which is created through external feedback. The reflective process is therefore part of a continuous interaction between the learner and the surrounding environment. This section examines concepts that focus on this interaction and its relation to reflection as process control at a micro level.

A single interaction is defined by two parts: an action performed by an actor and a response to this action from the system. With this regard, the use of a computer system as well as the related cognitive processes can be described as interaction chains. Garries, Ahlers, & Driskel (2002) define the "learning interaction cycle" by single interactions that are connected by the interpretation of a system's response by the learner. At this level a learning process is a flow of interactions between a learner and a corresponding system. This model has been inspired by concepts of self-regulated learning and has many similarities with the self-regulation model presented by Butler & Winne (1995). The main difference of the models provided by Butler & Winne (1995) and by Garries, Ahlers, & Driskel (2002) is their focus on different aspects of motivation and engagement.

Butler & Winne (1995) ground their model on the concept of self-regulation, in which a person continuously (and consciously) evaluates or assesses his or her actions, tactics, and strategies against the responses that were received from the environment. The results of this evaluation are then used to align goals and knowledge with the current situation, in which the person is situated. The motivation for the person's follow-up action is explained through the level of achievement and satisfaction in relation to the goals and prior experiences.

Garries, Ahlers, & Driskel (2002) relate their motivational model to the concept of flow (Csikszentmihaly, 1991), in which the motivation of a person is related to his or her goals as well as to complexity and difficulty of the tasks of a situation in relation to the person's perception of the situation. Whether a situated task is recognized as achievable and affordable depends on the person's (subconscious) estimation of the complexity and challenge of the task. The motivation for the person's follow-up actions is related to the emotional perception of a situation. This emotional perception is related to the prior experiences that are related to the current situation.

Both models treat the responding system as a block box. However, this does not mean that a system's responses are independent from the cognitive processes. According to Ley & Young (2001) system responses rely on three main principles in order to support the learning processes: firstly, the responses have to depend on the *monitoring* of a learners actions; secondly, the responses have to be *adaptive* to the learner's goals, actions, performance, achievements, and history; and finally, the *responses* have to relate to a learner's actions but do not need to be immediate reactions. This suggests that the system's responses should not only provide a connection to the current interaction, but consider previous learning activity as well.

Research on user modelling discusses various approaches to allow systems to relate and to adapt to previous actions of a learner (Kobsa, 2001, McTear, 1993). A more general approach has been taken in the domain of context aware computing (Dey, Abowd, & Salber, 1999; Dey, 2000, Zimmermann, Specht, & Lorenz, 2005). From this perspective the interaction cycle appears as a symmetrical process between an actor and a system that is connected by the system's interface (Figure 2.3). The actions of an actor on the interface are analysed and assessed by the system. Based on this analysis the system provides a response to the actions on the interface. The actor analyses and reflects on this response to judge the results of the initial action.

Zimmermann, Specht, & Lorenz (2005) describe an architecture for context aware systems. This architecture can get used as a substitute for the black box of the "external system" in the learning interaction cycle. The architecture has four layers and specifies operations on the data and information flow through a system from the learner input to the system response (Figure 2.4). The layers are the sensor layer, the semantic layer, the control layer, and the indicator layer. The first two layers are also considered as *interaction assessment* (Brusilovsky & Eklund, 1998) or *user modelling* (Kobsa, 2001; McTear, 1993). The last two layers are mentioned in the literature as *adaptation decision making* (Brusilovsky & Eklund, 1998). The control and indicator layer are commonly integrated as part of the user interface (Brusilovsky, 2001; Cheng & Vassileva, 2006; Kreijns, 2004).

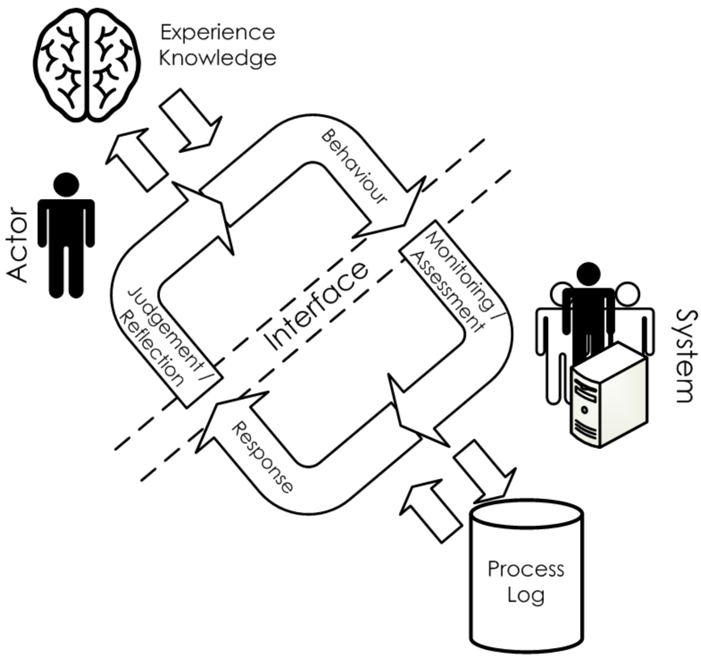

Figure 2.3: Learning Interaction Cycle

The *sensor layer* is responsible for capturing the actions of a learner. A *sensor* is a measuring unit for a single data type. The objective of sensor layer is to trace learner actions, but it may also include other measures that are relevant for the learning process. Sensors that track the interactions of a learner with the system are called *interaction sensors*. Sensors that do not gather information about a learner's interactions are called *contextual sensors*. Examples for contextual sensors are location tracker, or tagging activities and contributions of peer-learners. In the architecture the sensor layer adds data to the process log in order to allow the adaptation to the interaction history.

The *semantic layer* collects the data from the sensors and from the process log and aggregates this data into higher level information. The semantic layer defines operations or rules for processing sensor data (Cristea & Calvi, 2003). A definition of how the data from one or more sensors has to be transformed is called an *aggregator* (Dey, 2000, 2001). These rules are named according to their meaning, for instance *activity* or *interest*.

The aggregated information is interpreted by the *control layer* according to the history and context of a learner. The specific approach for interpretation is called a *strategy* (Cristea & Calvi, 2003). It defines the conditions for selecting and combining aggregators as well as their presentation according to the learner's context. A strategy also controls the personalization of aggregators.

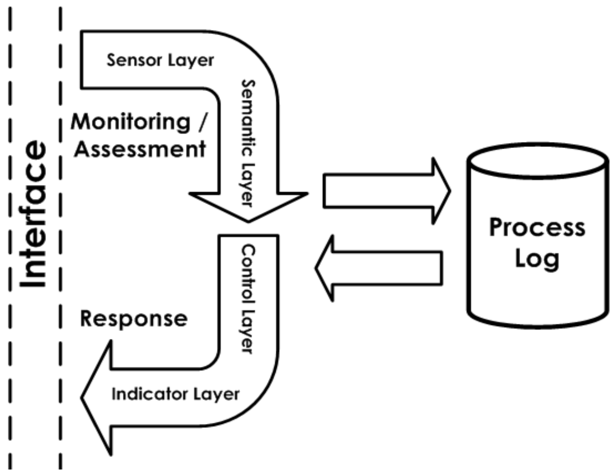

Figure 2.4: Layers for context-aware information processing

Finally, the aggregated information has to get presented to the learner. The *indicator layer* handles this part of the interaction. At this level the actual response is created by translating aggregated values into representations that are not just machine-readable but also accessible to humans. The active strategy of the control layer selects these representations and provides the aggregated information to them.

The first two layers are also considered as *interaction assessment* (Brusilovsky, Karagiannidis, & Sampson, 2001) or *user modelling* (Kobsa, 2001; McTear, 1993). This suggests the integration of the sensor and semantic layer, although they expose different feature sets: the sensor layer is concerned with data collection of "low level information […] including, for example, key strokes, task initiation and completion, answers of quizzes etc." (Brusilovsky, Karagiannidis, & Sampson, 2001) Its main objective is to organise incoming interaction footprints for further processing. In contrast, the semantic layer enriches, clusters, or transforms the data.

The last two layers are mentioned in the literature as *adaptation decision making* (Brusilovsky, Karagiannidis, & Sampson, 2001). The control and indicator layer are commonly integrated as part of the user interface (Chapter 3). This is not always desirable because different combinations of strategies and indicators have varying effects on the learning processes and outcomes (Specht & Kobsa, 1999).

The Information Visualization Pillar

Research in the field of cognitive psychology found that humans actively search for relations between their actions and their previous interactions. Such relations can be created with the help of indicators that provide information on the success and value of their interactions. This is especially the case if the actions are based on strategies that require alignment during the process (Jamieson-Noel, Chu, & Winne, 2004; Weber, 2003). This means that learners actively seek for indicators for verifying or modifying their learning strategies. In terms of the learning interaction cycle, this can be translated into indicators that use the *interaction history* to support learners while they are active in an environment.

Wexelblat & Maes (1999) define *interaction history* as traces of interactions between learners and objects. The authors argue that interaction history is extensively used by learners to guide actions, to make choices, and to find things of importance or interest (Wexelblat & Maes, 1999). Dron, Boyne, & Mitchell (2001) use the term *footprint* to indicate the value and meaning of each interaction in creating social spaces. The authors introduce this process as *stigmergy*. This concept has been previously applied for social navigation (Dieberger, 1997). Recently, Farzan & Brusilovsky (2005) use the term *interaction footprint* to refer to different traces that are left during the interaction process. Examples for such traces are notes about accessing a document in a repository, or the time a learner spent reading a document (Farzan & Brusilovsky, 2005).

When seen isolated, most interaction footprints are of little or no direct value to a learner. Of greater interest is information that is aggregated from interaction footprints. Visualisations of this aggregated information are one approach to provide meaningful connections to the learners' actions and the system's responses.

Erickson & Kellogg (2003) use interaction footprints of chats and discussion forums for graphical presentations of social dynamics in online spaces such as discussion forums or chats. The authors call their visualizations *social proxies*. These indicators are “minimalist graphical representations that portray socially salient aspects of an online situation” (Erickson & Kellogg, 2003, p. 23). These indicators present the status of and the relations between participants in an online environment. Displaying social interaction in social software to the users of the software is called by the authors: *social* *translucency* (Erickson & Kellogg, 2003, p. 18). One effect of social translucency has been reported as *waylay*. "Waylay refers to the practice in which a user monitors the Cookie [a social proxy] for signs of another person's activity [...], and then initiate contact." (Erickson & Kellogg, 2003, p. 35) The concept of waylay is different to what has been described as stigmergy (Dron, Boyne, & Mitchell, 2001). While stigmergy refers to pathways of activities that emerge through collaborative activities, waylay refers to virtual landmarks which are used by users to structure and plan their social activities, individually. Thus, stigmergy refers to the emerging structures that are created through social activity.

Waylay is related to a user's observations of public spaces. Kreijns (2004) identified a similar effect for group awareness indicators on distributed activities of peer user, which the author calls "social affordance". This effect has been observed with indicators that display the activity of other users within an online environment. Different to social proxies, these indicators are not limited to a single social space, but they provide information about the activities of users relative to the activities of their peers, without providing information how these activities are interrelated.

Social affordance refers to information that stimulates activities that are aligned to the social practice within a collaborative environment. According to the author social affordances create and depend on two relationships between the learner and the environment: the reciprocal relationship and the perception-action coupling. The reciprocal relationship is based on the social intentions of a learner and on how meaningful an environment can respond to these intentions. The perception-action coupling refers to the connection of the learners' recognitions of their environment, including the actions that they will perform in accordance to it (Kreijns, 2004).

Summary

This chapter discussed the three theoretical pillars of this thesis. The chapter started with some general remarks on learning in order to frame the domain of the research problem. The focus of this research lies on supporting learner controlled learning in weakly structured knowledge domains. This type of learning is also referred to as "self-directed learning". Three basic requirements for supporting self-directed learning were defined.

1. The support should stimulate engagement and reflection on learning processes.
2. The support has to be independent from a knowledge domain or specific working processes.
3. The support must not recommend learning actions to the learner.

The research grounds on three theories: the theory of "situated learning", "motivation and self-regulation", and "information visualisation for learning support". The theory of situated learning (Lave & Wenger, 1991) tells us, that learning is always part of social activity. From this perspective learning is a constructive process that is contextualised by the social environment in which it takes place. The research in this domain has identified several contextual dimensions and factors that are relevant to learning. These factors can be mapped to context dimensions of context aware computing (Zimmermann, Lorenz, & Oppermann, 2007). The theories on motivation and self-regulation emphasize the connectedness of action, feedback, and reflection. This connectedness puts reflective processes as a part of ongoing social *interaction*. The chapter discussed two models that embed reflection as part of the interaction of a learner with an external system. The first model focuses on self-regulation (Butler & Winne, 1995). The second model focuses on engagement (Garries, Ahlers, & Driskel, 2002). These models were extended with a general architecture for context-aware systems. The resulting *learning interaction cycle* allows to design and structure feedback systems for self-directed learning. The third pillar of this research is information visualisation for learning support. The related research used visualisations of "interaction footprints" to support learning in open online environments (Dron, Boyne, & Mitchell, 2001; Erickson & Kellogg, 2003; Kreijns, 2004). This research indicated that minimalist information visualisations that are based on the learners' interaction footprints can stimulate social interactions. The related concept is "social affordance", which describes the degree to which a visualisation lays ways for the learners to participate in a social environment.

The learning interaction cycle provides a generic system model that helps understanding self-directed learning processes at a micro level. The contextual dimensions that are based on theories of situated learning and context aware computing help to identify variables that influence the learning interactions. The combined concepts help to understand, to design, and analyse contextualised support for self-directed learners. The visualisations of interactions can be considered as special types of feedback that can be fitted to this framework.

The three pillars leave a white space in their common intersection. This space can be titled as "contextualised indicators for learner support". Based on the related research it can be expected that the social affordance of interaction footprint visualisations depends on the interaction context of a learner.

Chapter 3
Sensors and Indicators to Support the Learning Interaction Cycle[1]

This chapter focuses on the relevant information for collecting and presenting contextual information, its effects and impact on the learning interaction cycle, and mechanisms of controlling it. The core principle of the learning interaction cycle is the interaction of learners with their learning environment. Previous research highlights that such interaction is related to the experience and progress of learners. However, a conceptual gap between the learner actions within a learning environment and the responses that are provided to the learners is identified. To bridge this gap a layered model of context-aware systems that meets the requirements for supportive responses has been adopted. The model has four layers and describes the information processing of interaction footprints of learners in a learning environment: the sensor layer, the semantic layer, the control layer, and the indicator layer. This model has been applied to analyse the results that are reported in the literature.

Indicators are mechanisms to provide *simplified information* that is valuable to a task. With some background knowledge we can understand the meaning of an indicator without the need of knowing about the details of the underlying process or mechanism. For instance, the fuel needle of a car is an indicator. Whoever is familiar with driving cars knows that the fuel needle indicates how much fuel is left in the tank and that it is useful to check it regularly, if one wants to keep driving instead of walking. We understand that it is necessary to find a filling station if the fuel needle points towards the lower end of the scale. However, to make the appropriate decision it is not necessary to know the size of the fuel tank, the exact amount of fuel that is left in it, or about the fuel consumption of the motor. Some cars switch on an additional light, if the fuel level falls below a critical level. Such indicators focus our attention on important facts that we would miss or ignore otherwise. The telephone bell is another example for such indicators: it indicates that someone is calling on the phone. Without it we would not be aware of the incoming call, unless we were checking the telephone line actively. This leads to another characteristic of indicators: they help us to focus on relevant information when it is required, whereas we do not have to bother about it most of the time.

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[1] This chapter is based on:
Glahn, C., Specht, M., & Koper, R. (2008). Smart indicators to support the learning interaction cycle. *International Journal for Continuing Engineering Education and Life-Long Learning, 18*(1), 98-117.

This chapter is a review on current approaches of using indicators to support the learning interaction cycle. The learning interaction cycle addresses the interaction between a learner and a learning environment as the core of the learning process. Previous research indicated that providing contextual information via indicators is beneficial for supporting learning processes. Contextual information stimulates the learners' engagement in and commitment to the learning process (Beenen et al., 2004; Ling et al., 2005; Rashid et al., 2006); helps to raise awareness of and stimulates reflection about acquired competences (Kreijns, 2004; Kreijns & Kirschner, 2002); and support thoughtful behaviour in navigation and on learning paths (Van Nimwegen, Van Oostendorp, Burgos, & Koper, 2006). This chapter analyses different approaches of using indicators to support the learning interaction cycle.

This chapter focuses on the relevant information for collecting and presenting contextual information, its effects and impact on the learning interaction cycle, and mechanisms of controlling it. In other words, it analyses variables and concepts that make indicators on the learning process ‘smart’. The objective is to enrich learning experiences in informal and non-formal learning environments, such as on-line communities of practice. Indicators of contextual information display effects and progress of the ongoing learning process where they otherwise would be hidden to the learner.

The next section illustrates the problems and the underlying concepts with a hypothetical scenario for an application of context-aware indicators. This scenario is used to elaborate one view on the learning interaction cycle by developing a layered model for smart indicators. This model is based and validated on educational requirements. Later the model is applied to analyse the existing research, which focuses on the approaches of collecting data from the learners, as well as aggregating and indicating information back to them. The chapter concludes with an analysis of the reported effects of indicators for the learning process and derives some questions for further research from these results.

The hypothetical scenario of Tim, the accountant

For the last eight years Tim has been working as an accountant in a small company specialised in the production of medical instruments. He considers his job as boring, but since Tim and his wife have bought a small house he depends on his job.

Recently, a new ERP system has been installed in his company and Tim has received an introductory seminar to the new environment. Unfortunately, he has no fellow colleagues to exchange and discuss about experiences in using the new system, but he feels that he could do a better job if he would have a better understanding of how to use the different modules, components and interfaces of the new software. After hours of browsing the web searching for information, he subscribed to an on-line community in which problems, news and best practices about the ERP system are presented and discussed.

As Tim logs in the first time he recognises that the community portal provides an 'activity' widget. The widget displays the number of pages and forum postings Tim has accessed while he is clicking through the community's web-site. The widget displays a bar chart, in which a coloured bar grows a bit with each link that Tim follows. Tim receives more detailed information about his activity when he clicks on the widget, such as history of pages he has visited.

At his fifth visit to the community portal, Tim receives a message that he now has passed the starter phase and Tim is asked if he likes the widget to display his activity level in relation to the rest of the community. Tim likes this idea and activates the new function.

The new widget has three components: first it shows the number of actions Tim has performed today at the community portal. These actions include downloads of documents, reading of postings at the community's discussion forum and contributions to forums and Wiki pages. Second, it indicates the average number of actions that were performed today. Third, it shows Tim's average number of actions that he has performed during the visits of the last four weeks. Now Tim can see that he is accessing more information than the average community member.

An additional bar chart appears in the widget after some time. This second bar chart has the label 'effort'. It has a similar set up like the one Tim is already familiar with. The chart displays the relation of the time Tim spends reading information and the size of that information. Like the first bar chart, it has also two additional markers: one shows the same value for the community, the other one displays the value for the last four weeks.

When Tim investigates the two charts he sees that his activity level is quite high, but the effort appears to be quite low. Tim wonders about this and understands that he was flipping through the information most of the time, but did not read thoroughly. He decided to focus a bit more on the examples and relate them to his daily tasks in the office. Throughout the next sessions Tim realises that he develops a better understanding of the ERP system, while his effort bar and activity bar align to each other.

Over the time Tim starts to contribute regularly to the community's forum and Wiki pages. He sees that his activity widget started to display a third bar chart. This bar chart reports on the rates of his contributions that are accessed by other users. He sees that his contributions get high access rates and he is satisfied that he could provide useful information back to the community.

One day Tim visits the community portal and sees a new marker on the third chart about his contributions in the activity widget. This marker has the shape of a star. He becomes curious what it could mean and checks his report in more detail. The information shows that some of his contributions were highly rated by other members of the community as helpful. Finally, Tim starts to understand that he developed some expertise in mastering the ERP system – and that his knowledge is also valuable for his job.

The learning interaction cycle

The scenario refers to principals of what Schön (1983) calls a "reflective practitioner" in a self-organised learning situation. Schön's theory states that reflection on practices is a core principle for competence development in the professions (Schön, 1983, 1987). In the scenario, Tim's awareness of and reflection about his learning process is triggered by system generated information about his learning activities and those of his peers.

The previous chapter introduced the *learning interaction cycle*. It described the underlying model for system support of a learner's reflection, where the support is based on the learner's activities and context. The concept of learning interaction cycles addresses learning interactions as the core of the learning process.

Schön's (1983) concept of *reflection in action* highlights also the relation of past experiences and the current situation of a practitioner. In terms of the learning interaction cycle this can be translated to utilizing the interaction history to support learners while they are active in a learning environment. Wexelblat & Maes (1999) define *interaction history* as traces of interactions between users and objects. The author argues that interaction history is extensively used by users to guide actions, to make choices, and to find things of importance or interest (Wexelblat & Maes, 1999). Dron, Boyne, & Mitchell (2001) use *footprint* to indicate the value and meaning of each interaction to the interaction history of an object in a social space. The authors introduce the term *stigmergy* to describe the role of footprints for emerging social spaces. This concept was already applied for supporting social navigation (Dieberger, 1997). Recently, Farzan & Brusilovsky (2005) use the term *interaction footprint* to refer to different traces that are left during the interaction process. Such traces can be a note about accessing a document in a repository, or the time a learner has spent reading a document (Farzan & Brusilovsky, 2005).

Humans actively search for relations to their previous interactions, in particular for indicators that provide information on the success and value of their interactions. This is especially the case if the actions are based on strategies that require alignment during the process (Jamieson-Noel, Chu, & Winne, 2004; Weber, 2003). In other words, learners continuously seek for indicators that help them to verify or modify their learning strategy.

When seen isolated, most interaction footprints are of little or no direct value to a learner. As discussed in Tim's case, it is the higher level information or combinations of information that triggers his awareness and reflection. In the scenario the higher level information is information about *learning activity* within the community.

The scenario outlines that the possible indicators depend on the learner's history within the learning environment: certain information can be useful during early phases while the same information is of less value to the learner in later stages of the learning process. In the beginning, Tim receives information that is deduced from his activity in the community system. The provided information evolves while more interaction footprints become available. For Tim it makes no sense to receive information about peer ratings on his contributions if he has nothing contributed; but if this information becomes available it can be of higher value to Tim than his access rate of the learning material.

Requirements for smart indicators

In order to provide smart indicators for learner support in the learning interaction, it is necessary to develop an understanding about general principles of this process. These principles are the foundation of the core requirements for smart indicators.

From research on feedback and self-regulated learning (Butler & Winne, 1995; Ley & Young, 2001; Mory, 2003; Orange, 1999) we learn that *external feedback* is needed for the learning process. According to Ley & Young (2001) it relies on three general principles:

- External feedback relies on monitoring of the learning actions and the learning context.
- External feedback has to adapt according to a learner's goals, actions, performance, outcomes and history.
- External feedback is a response to a learner's actions, which it is not necessarily immediate.

These principles are relevant to this research for two reasons. First, external feedback is a special kind of response within the learning interaction cycle (Butler & Winne, 1995; Mory, 2003). Second, this research addresses learning in the professions and in particular learning in open environments such as communities of practice, as the scenario already illustrates. Considering general principles of self-regulated learning is reasonable for the support of learning interactions in such contexts, because adult learners commonly demand more control on their learning activities (Illeris, 2003).

The principles of Ley & Young (2001) focus on the effects of responses on the learner. However, they do not consider the way of presenting this information to the learners. This is partly due to the fact, that they are based on the results from research on self-regulated learning or feedback. The research focuses largely on cognitive processes of the learner. Generating and communicating responses to the learner are usually beyond the scope of such research. However, in terms of the learning interaction cycle, indicating information to a learner is a critical factor (Dey & Abowd, 1999; Kreijns, 2004).

Besides the information that relates directly to the user, several authors (Dieberger, 1997; Dron, Boyne, & Mitchell, 2001; Farzan & Brusilovsky, 2005; Kreijns, 2004) stress the relevance of contextual parameters on the learning process. Being informed on the social, spatial and logical context helps learners to select activities and assess the results of their actions.

To reflect indicators and context explicitly, an extension of Ley & Young's principles is proposed:

- External feedback relies on monitoring of the learning actions and the learning context.
- External feedback has to adapt according to a learners' goals, actions, performance, outcomes, and history as well as to the context in which the learning takes place.
- External feedback is an indicator that responds to a learner's actions or to changes in the context of the learning process, where the response is not necessarily immediate.

Analytical model

Different to research on self-regulated learning or feedback, this research addresses the system's side of the learning interaction cycle. Therefore, the analytical model of the present research describes information processing from sensors to indicators, rather than the cognitive processes of the learner. In this study, the analytical model is derived from concepts of context-aware systems (Dey, 2000; Dey, Abowd, & Salber, 1999; Zimmermann, Specht, & Lorenz, 2005). Dey (2000) defines context as follows:

> *"Context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves." (Dey, 2001, p. 5)*

Chapter 2 introduced a general architecture for context aware and context adaptive systems. This architecture has four logical layers: the sensor layer, the semantic layer, the control layer, and the indicator layer. This review applies these four layers to analyse the literature, because the model meets the four principles of external feedback:

- *Monitoring* is facilitated by the sensor and the semantic layer of the model. The sensor layer collects footprints of the learning interactions. The semantic layer clusters and organises the data provided by the different sensors in order to make it accessible for presentation or further processing.
- *Adaptation to the learner's goals, actions, performance, outcomes, history* and learning context is handled by the strategies of the control layer. Depending on those strategies the results of the semantic layer selects parts of that information for indicating them to the learner. The control layer uses strategies to select aggregators that are appropriate to a learner's situation. A strategy in the control layer may also adapt timing and style of an indication.
- Each indicated information is a *response on the learners' actions or on the context of the learning process* because it results from a monitoring process. *Indicating the results back to the learner* is managed by the indicator layer. It transforms the information that is provided by the underlying layers regarding the interface that is used by the learner.

The systematic analysis of the existing research in this chapter is based on this model. According to the four layers of the model, the literature is reviewed on the sensors, aggregators, strategies, and indicators that were applied. A second step focuses on the reported effects on the learning process.

Current perception of the learning interaction support

This section reports on four different research perspectives of indicating information that is relevant for a learning process. These research perspectives are:

- Approaches from the domain of adaptive hypermedia (Ahn, Brusilovsky, & Farzan, 2006; Bretzke & Vassileva, 2003; Cheng & Vassileva, 2005a, 2005b; Farzan & Brusilovsky, 2005; Vassileva, 2004).

- Solutions for social awareness web- and collaborative environments (Ellis & Dix, 2004; Kreijns, 2004; Kreijns & Kirschner, 2002; Mealha, Sousa Santos, Nunes, & Zamfir, 2004).
- Recommendation systems (Klerkx, Duval, & Meire, 2004; Ng & Martin, 2004; Nguyen, Huang, & Hawryszkiewycz, 2004)
- Approaches that focussed only on contextual information without taking any user interaction footprints into account (Gatalsky, Andrienko, & Andrienko, 2004).

This review does not consider solutions that focus entirely on social interaction, such as chat or instant messaging as it was reported by Erickson and his colleagues (e.g. Ding et al., 2007; Erickson et al., 1999). Also, this review does not cover approaches of the use of mobile devices in education, or ubiquitous interactions in smart places.

The selection criteria for the literature were that the reported approaches utilize graphical indicators to display information that is relevant to learners. All approaches are analysed according to the layers of the model that was introduced in the previous section.

Based on these criteria a wide range of approaches that utilise sensors, aggregators, strategies and indicators for different purposes were found. In general, most work applies one strategy that is based on a fixed set of sensors and just a single aggregator (Cheng & Vassileva, 2005a, 2005b; Ellis & Dix, 2004; Farzan & Brusilovsky, 2005; Marcos, Martinez, Dimitriadis, & Anguita, 2006; Mealha, Sousa Santos, Nunes, & Zamfir, 2004; Ng & Martin, 2004). Also it appears that the problem is partly recognised as a problem of *information visualisation.*

Sensors to monitor user interaction

At the input level of the analytical model is the sensor layer. Sensors capture interaction footprints and make them available for further processing. At this level the literature was analysed regarding to the sources used in the interaction process. Four main sensor groups were identified. The sensors within each group vary on the actual data they capture, but share common characteristics. The four sensor groups are:

- *Time sensors* cover all timing measures, such as timestamps or durations;
- *Social context sensors* track the interaction behaviour of the peers of a user;
- *User sensors* monitor the interactions of a single user;
- *Environment sensors* collect data about the context of a learner.

Time sensors cover concepts such as timestamps, for instance the event time (Gatalsky, Andrienko, & Andrienko, 2004), such as page accesses (Ellis & Dix, 2004; Greer et al., 1998) or document manipulation (Kreijns, 2004; Kreijns & Kirschner, 2002); durations, or more precisely the time spent reading a document (Farzan & Brusilovsky, 2005); and time intervals such as the beginning and the end of user sessions (Mealha, Sousa Santos, Nunes, & Zamfir, 2004).

Social context sensors refer to all measures of the interaction behaviour related to the peers of the user who is the target of the response. Social context sensors are not used to indicate the collected data for each user, but are aggregated for a group of users (Farzan & Brusilovsky, 2005; Kreijns, 2004). These sensors include the following aggregations.

- Information access (Bretzke & Vassileva, 2003; Cheng & Vassileva, 2005a, 2005b; Ellis & Dix, 2004; Farzan & Brusilovsky, 2005; Mealha, Sousa Santos, Nunes, & Zamfir, 2004)
- Number of contributions such as documents and forum posts; (Cheng & Vassileva, 2005a, 2005b)
- Peer ratings, comments and reviews (Bretzke & Vassileva, 2003; Cheng & Vassileva, 2005a; Greer et al., 1998; Ng & Martin, 2004)
- Search terms used (Bretzke & Vassileva, 2003; Klerkx, Duval, & Meire, 2004)
- Connection to other peers (Bretzke & Vassileva, 2003; Marcos, Martinez, Dimitriadis, & Anguita, 2006)
- Self assessment (Greer et al., 1998)
- Time a task has been conducted by a user (Greer et al., 1998).

These sensors collect information about the social context of a learner.

User sensors cover those sensors that measure the interaction of the user who will receive the response. In principal, these sensors are the same as social context sensors. The main difference is that these sensors capture data directly from the learner for whom the information will be aggregated. Claypool, Le, Wased, & Brown (2001) analysed and validated a set of sensors (which the authors call indicators) according to the reliability and validity of these sensors for measuring a user's interest and attention. From that study five groups of user sensors are applicable for this review:

- Explicit interest sensors like sensors that capture for example the text a user has typed into a query form.
- Marking interest sensors are for example sensors that track the ratings about the quality of a document.

- Manipulation interest sensors such as sensors that recognise if a user has created or changed an object.
- Navigation interest sensors like sensors that track which links a user follows.
- External interest sensors that track the keywords of a learning object's meta-data, for instance.

	User	Social Context	Environment	Time
Ahn, Brusilovsky, & Farzan, 2006	Requested pages; goal definition	Requested pages; annotation; ratings	Keywords; content meta-data	
Bretzke & Vassileva, 2003		Requested pages; ratings; contributions; annotations; peer relations; used search terms		
Cheng & Vassileva, 2005b; Vassileva, 2004		Requested pages; ratings; contributions; annotation		Interval (Online Time)
Cheng & Vassileva, 2005a	Forum contributions	Forum postings; ratings		
Ellis & Dix, 2004		Requested pages		Time stamp of page access
Farzan & Brusilovsky, 2005		Requested pages	Content meta-data	Duration (reading Time)
Gatalsky, Andrienko, & Andrienko, 2004			Geographical position; related events	Event time
Greer et al., 1998	Self recognition questionnaire; times of task completion	Ratings		Action time stamp
Kreijns, 2004; Kreijns & Kirschner, 2002	Action counter	Action counter; peer notifications		Action time stamp
Klerkx, Duval, & Meire, 2004	Document selection; search query		LOM Data-sets; DRM privileges;	
Marcos, Martinez, Dimitriadis, & Anguita, 2006	Contributions	Contributions; rating; Relations		
Mealha, Sousa Santos, Nunes, & Zamfir, 2004	Session identifier		Content meta-data; link structure	Duration (reading time)
Ng & Martin, 2004	Document selection	Rating	Content meta-data	
Nguyen, Huang, & Hawryszkiewycz, 2004			Content meta-data; link structure	

Figure 3.1: Sensor usage reported by the literature, ordered by origin

Environment sensors are those sensors that collect data about the context of a learner. These sensors may capture the following types of information.

- Spatial information (Greer et al., 1998)
- Learning object meta-data (Farzan & Brusilovsky, 2005; Klerkx, Duval, & Meire, 2004; Mealha, Sousa Santos, Nunes, & Zamfir, 2004; Nguyen, Huang, & Hawryszkiewycz, 2004)
- Hyper-link structures (Gatalsky, Andrienko, & Andrienko, 2004; Nguyen, Huang, & Hawryszkiewycz, 2004).

The review indicates that time and social context sensors play a key role in the reviewed literature (Figure 3.1). These types of sensors are heavily used in higher level aggregators.

Although user sensors were also mentioned, they are mostly used to select peer user and context information. In combination with social context sensors the user sensors generate the learning history. This interaction history is then used to bias the data from peer user sensors (Cheng & Vassileva, 2005a, 2005b; Greer et al., 1998). In combination with environmental sensors, actual user sensors refer to previous or current selections or search terms that are used by a learner (Klerkx, Duval, & Meire, 2004; Mealha, Sousa Santos, Nunes, & Zamfir, 2004). Only Kreijns (2004) describes an indicator that is entirely based on actual user sensors.

Despite the range of identified sensor combinations, it appears that a group of sensors is particularly popular (Figure 3.1).

- Among *time sensors* the event time (including time stamps of page accesses) was mentioned four times (Ellis & Dix, 2004; Gatalsky, Andrienko, & Andrienko, 2004; Greer et al., 1998; Kreijns, 2004).
- The most applied *social context sensors* are *peer ratings* (Ahn, Brusilovsky, & Farzan, 2006; Bretzke & Vassileva, 2003; Cheng & Vassileva, 2005a, 2005b; Greer et al., 1998; Marcos, Martinez, Dimitriadis, & Anguita, 2006; Ng & Martin, 2004) and *requested pages* (Ahn, Brusilovsky, & Farzan, 2006; Bretzke & Vassileva, 2003; Cheng & Vassileva, 2005b; Ellis & Dix, 2004; Farzan & Brusilovsky, 2005).
- *Content meta-data* is a popular environmental sensor (Ahn, Brusilovsky, & Farzan, 2006; Farzan & Brusilovsky, 2005; Klerkx, Duval, & Meire, 2004; Mealha, Sousa Santos, Nunes, & Zamfir, 2004; Ng & Martin, 2004; Nguyen, Huang, & Hawryszkiewycz, 2004).

- *Contribution sensors* are used for gathering information about both the user and social context (Bretzke & Vassileva, 2003; Cheng & Vassileva, 2005b; Marcos, Martinez, Dimitriadis, & Anguita, 2006).

Meaningful information through semantic aggregators

On the levels of the semantic and the control layer a great number of approaches were found. The review indicated that the identified approaches for each layer are closely related to the goals of the overall application. Therefore, interoperability between systems and transferring a solution to other domains or data sources was not considered by the literature under review.

It was found that in the majority of the research a single aggregator and a single strategy are used (Figure 3.2). Only few researches were interested in multiple semantic aggregators. In these cases personalisation, in terms of control strategies, is of no interest (Gatalsky, Andrienko, & Andrienko, 2004; Klerkx, Duval, & Meire, 2004) or is conducted by applying user profile filters to the information from the semantic layer (Bretzke & Vassileva, 2003).

The literature discussed three types of semantic aggregators:

- Simple arithmetic aggregators
- Naïve statistic aggregators
- Network aggregators

Simple arithmetic aggregators cover all approaches that include only basic arithmetic operations, such as the following

- Sums (Bretzke & Vassileva, 2003; Ellis & Dix, 2004; Farzan & Brusilovsky, 2005; Kreijns, 2004; Kreijns & Kirschner, 2002)
- Enumerations (Greer et al., 1998; Mealha, Sousa Santos, Nunes, & Zamfir, 2004)
- Equity (Nguyen, Huang, & Hawryszkiewycz, 2004).

Naïve statistics refer to those approaches that aggregate the sensor data with a simple statistical function like the arithmetic mean (Cheng & Vassileva, 2005a; Ng & Martin, 2004).

Network aggregators analyse relations between learners and information (Ahn, Brusilovsky, & Farzan, 2006; Bretzke & Vassileva, 2003; Cheng & Vassileva, 2005b; Marcos, Martinez, Dimitriadis, & Anguita, 2006). The identified approaches provide information on the context of the learner. Others make use of environmental relations (Gatalsky, Andrienko, & Andrienko, 2004; Klerkx, Duval, & Meire, 2004). In such cases the information of a system is organised according to a user's selection or profile. This helps learners to understand the structure of an information space while they explore it.

	Semantic aggregator	Control strategy
Ahn, Brusilovsky, & Farzan, 2006	Multiple	Single
Bretzke & Vassileva, 2003	Multiple	Single
Cheng & Vassileva, 2005b; Vassileva, 2004	Single	Single
Cheng & Vassileva, 2005a	Single	Single
Ellis & Dix, 2004	Single	Single
Farzan & Brusilovsky, 2005	Single	Single
Gatalsky, Andrienko, & Andrienko, 2004	Multiple	N/A
Greer et al., 1998	Single	Multiple
Kreijns, 2004; Kreijns & Kirschner, 2002	Multiple	N/A
Klerkx, Duval, & Meire, 2004	Multiple	N/A
Marcos, Martinez, Dimitriadis, & Anguita, 2006	Single	Single
Mealha, Sousa Santos, Nunes, & Zamfir, 2004	Single	Single
Nguyen, Huang, & Hawryszkiewycz, 2004	N/A	Single
Ng & Martin, 2004	Single	Single

Figure 3.2: Types of semantic aggregators and control strategies

Control strategies for adaptation

For the control layer no approaches were identified that dynamically adapt the control strategy according to the learner's prior activities. In those cases where multiple control strategies were identified, the approaches were concurrently available to the users. Nonetheless, the review identified three different groups of control strategies:

- *Null strategies* select information from the semantic layer according to the users' preferences. The data from the semantic layer is not further processed. Personalisation means at this level that whether information is accessible or not, depends on a learner's profile. The null strategies include those approaches that do not personalise the information at all. Null strategies are applied in social awareness systems (Kreijns, 2004; Kreijns & Kirschner, 2002; Marcos, Martinez, Dimitriadis, & Anguita, 2006) and navigation support for content repositories or databases (Gatalsky, Andrienko, & Andrienko, 2004; Klerkx, Duval, & Meire, 2004).

- *Clustering strategies* organise the information from the semantic layer into clusters or groups. Clustering organises the similar information according to the learner's profile. The clustering process includes reorganising the information before it is passed to the indicator layer. This approach is used in content recommendation systems (Ellis & Dix, 2004; Farzan & Brusilovsky, 2005) but also for navigation support in content repositories (Nguyen, Huang, & Hawryszkiewycz, 2004).
- *Scoring and sorting strategies* create an order between sensor measures, users or contents. This approach is of a higher level than clustering, because it reflects the order between elements during the clustering process. This approach is used in content recommendation systems (Mealha, Sousa Santos, Nunes, & Zamfir, 2004; Ng & Martin, 2004) as well as in collaboration support (Bretzke & Vassileva, 2003; Cheng & Vassileva, 2005a, 2005b).

Indicator Types

The indicators are those parts of the responding system that present the interaction footprints to the learners. Therefore, they often depend directly on the system in which they are used. With this regard, four groups of indicators were identified:

When *embedded content indicators* are used, the information indicator is embedded in the content structure. This includes modified backgrounds, highlighted content and coloured links (Farzan & Brusilovsky, 2005).

1D-graphical indicators include all indicators that present information in scales or embedded with other content. This includes approaches such as status indicators that use colour encodings to indicate the following information.

- Level of a user in the system (Bretzke & Vassileva, 2003; Cheng & Vassileva, 2005a, 2005b)
- Ratings (Cheng & Vassileva, 2005b)
- Progress (Bretzke & Vassileva, 2003; Ng & Martin, 2004).

2D-graphical indicators help display relations between information in 2D space. These can be of the following types.

- Relations of complex hierarchical data such as it can be found in content repositories (Klerkx, Duval, & Meire, 2004)
- Computer supported collaborative work (CSCW) (Marcos, Martinez, Dimitriadis, & Anguita, 2006)

- Social interaction patterns on a web site (Ellis & Dix, 2004; Nguyen, Huang, & Hawryszkiewycz, 2004).

If very complex information has to get reported to the learner, *3D graphical indicators* can be used. These indicators display complex structures (Mealha, Sousa Santos, Nunes, & Zamfir, 2004) or different information dimensions in a 3D space (Gatalsky, Andrienko, & Andrienko, 2004).

Validity of the reported approaches

One result of the review is that not all of the reported aggregators and strategies are based on empirically validated concepts. On the one hand this indicates explorative research and the need of further empirical work. On the other hand, it is difficult to validate an approach or to explain the origin of effects on the learning process. For this reason this section analyses the validity of those approaches that are discussed in this review. It has been assumed validity of an approach on one layer, if other research has been quoted, which had successfully applied the approach and/or found similar effects. Figure 3.3 shows which parts of the approaches are based on previously validated concepts. This task did not include the underlying models on internal and statistical validity or on predictability, because the reviewed literature does not provide sufficient information for this task.

Although most authors refer to other research with regard to the sensors they have applied, these references regularly do not provide empirical validity on the sensor. Only Farzan & Brusilovsky (2005) argue the selection of the sensors on the base of a correlation between the sensors and the information that should be aggregated from them.

Most authors define aggregators and conditions of using them in a scenario, but only a few authors specify their aggregators precisely (Ahn, Brusilovsky, & Farzan, 2006; Cheng & Vassileva, 2005a, 2005b; Farzan & Brusilovsky, 2005). These aggregator definitions are sound, but lack of empirical evidence regarding their relevance for the learning process. This may lead to wrong expectations and even disappointment of the learners (Farzan & Brusilovsky, 2005).

Although most authors mention a strategy for their approach, no one provided a specification for it. Only for one approach the authors base the use of the strategy on external references (Cheng & Vassileva, 2005b; Vassileva, 2004). The reason for this could be the tight relation between the strategy and the indicator that was presented with many approaches.

	Sensor layer	Semantic layer	Control layer	Indicator layer
Ahn, Brusilovsky, & Farzan, 2006	OK	-	-	OK
Bretzke & Vassileva, 2003	-	-	-	OK
Cheng & Vassileva, 2005b; Vassileva, 2004	-	(OK)	OK	OK
Cheng & Vassileva, 2005a	OK	-	-	OK
Ellis & Dix, 2004	OK	OK	-	OK
Farzan & Brusilovsky, 2005	OK	-	-	OK
Gatalsky, Andrienko, & Andrienko, 2004	OK	OK	N/A	OK
Greer et al., 1998	OK	-	-	-
Kreijns, 2004; Kreijns & Kirschner, 2002	-	-	N/A	OK
Klerkx, Duval, & Meire, 2004	OK	-	N/A	OK
Marcos, Martinez, Dimitriadis, & Anguita, 2006	OK	-	-	OK
Mealha, Sousa Santos, Nunes, & Zamfir, 2004	OK	OK	-	OK
Nguyen, Huang, & Hawryszkiewycz, 2004	OK	-	-	OK
Ng & Martin, 2004	OK	-	-	-

Figure 3.3: Components that are grounded in research

Almost all approaches adopted an indicator that has been successfully implemented elsewhere. Where the indicators where entirely graphical, the indicators have been developed in the field of information visualisation (Ellis & Dix, 2004; Gatalsky, Andrienko, & Andrienko, 2004; Klerkx, Duval, & Meire, 2004; Mealha, Sousa Santos, Nunes, & Zamfir, 2004; Nguyen, Huang, & Hawryszkiewycz, 2004). These approaches have in common that they refer neither to usability nor to educational research to argue the use of an indicator. The reason for this can be that these aspects were not the primary focus of that research. Where the indicator had a clear educational purpose, the use of the indicator was also grounded in that field (Bretzke & Vassileva, 2003; Cheng & Vassileva, 2005a, 2005b; Kreijns, 2004; Kreijns & Kirschner, 2002; Vassileva, 2004). Embedding the indicator into the content structure of the learning environment is an alternative approach of applying indicators (Ahn, Brusilovsky, & Farzan, 2006; Farzan & Brusilovsky, 2005). Such approaches appear useful if the indicator helps the learner to navigate through the content. Therefore, it is not surprising that the use of these indicators is grounded in the research of adaptive hypermedia.

Effects on the learning interaction cycle

A large number of the analysed approaches did not report effects of indicating information on the learning interaction cycle, but described the technology and possible solutions. Nevertheless, some effects on the learning interaction cycle were found by empirical evaluation and reported (Cheng & Vassileva, 2005b; Farzan & Brusilovsky, 2005; Kreijns, 2004; Marcos, Martinez, Dimitriadis, & Anguita, 2006).

Cheng & Vassileva (2005b) successfully stimulated learner contributions to the learning environment through the additional indicator. In this case the strategy implemented a rewarding mechanism. The users became aware of this rewarding mechanism and set strategic goals according to it. As a side effect, the authors reported a decrease in the quality of the contributions.

Farzan & Brusilovsky (2005) reported that learners participated more continuously to a course if the indicator was provided. The findings indicate that the non-rewarding mechanism helped learners to identify and use high-quality material in a content repository. However, the authors assume that the positive effects were constrained because the actual decision of which contents to use was to the learner.

Marcos, Martinez, Dimitriadis, & Anguita (2006) found positive effects of providing graphical indicators. This includes higher commitment and more contributions in collaborative activities.

Kreijns reports that learners felt more aware about their presence in a virtual learning environment, when they received graphical responses (Kreijns, 2004, p. 190). However, the author also detected that the provided graphical group awareness tool encouraged spying among peers. Kreijns concludes that graphical representations should provide suggestions of their usage, in order to avoid false expectations or misuse.

Conclusions and questions of further research

This chapter focused on the relevant information for collecting and presenting contextual information, its effects and impact on the learning interaction cycle, and mechanisms of controlling it. The core principle of the learning interaction cycle is the interaction of learners with their learning environment. Previous research highlights that such interaction is relevant for the experience and progress of learners. However, a conceptual gap between the learner actions within a learning environment and the responses that are provided to the learners has been identified. To bridge this gap a layered model of context-aware systems and self-directed learning has been applied. This model meets the requirements for supportive responses as they were defined by Ley & Young (2001). The model has four layers and describes the information processing of interaction footprints of learners in a learning environment: the sensor layer, the semantic layer, the control layer, and the indicator layer. This model provided a guiding line for analysing the results that were reported in the literature.

It is remarkable that in the reviewed literature, the sensors and indicators where grounded on existing research, while this was not always confirmed for aggregators and strategies. Also, most studies reported on combinations of a single approach each on the semantic and the control layer. Taking these results into account, it appears that the research on factors for generating responses to learner is in an early stage. This finding on the state of research is confirmed by the identified experimental settings and effects of indicators on the learning process that were reported by prior research.

The review did not identify case or experimental studies that were similar to the scenario that has been described earlier in this chapter. In other words, there is no evidence whether or not "smart indicators" have a positive impact on the learning interaction cycle and on the learning process. This leads to fundamental questions for further research:

> *What contextual information is relevant to support the learning process and does this information change throughout the individual learning process?*

This question addresses the problem of the learning interaction cycle at large. It addresses the way how to provide meaningful responses to learners, as it has been reported in the literature. From a more technological perspective, this question can be rephrased as:

> *How can a system collect data and aggregate contextual information in a way that it can provide meaningful information in the different stages of a learning process?*

This second question addresses the effects of indicators on the learning process. The literature does not provide clear evidence of positive effects of using indicators in the learning process. It appears that the even similar approaches result in different effects. Therefore are answers to the following question essential for providing 'smart indicators':

What is the effect of different aggregators, strategies and indicators on the learning process and how can they effectively be combined and applied for supporting the learning process?

Although, the review of the literature provided several approaches to supporting learners, the answers to these questions remained unspecific. Further research has to address these questions, empirically.

Chapter 4
Smart Indicators on Learning Interactions[1]

Indicators help actors to organise, orientate, and navigate through environments by providing contextual information that is relevant for performing learning tasks. This chapter analyses the requirements, presents a model and an initial prototype of a software system that uses smart indicators to support learners to be more engaged into the learning process. It is argued that indicators need adaptation as learners develop on their learning paths in order to support interactions throughout the learning process. The learning interaction cycle of self-regulated learning is used as a model for developing an architecture that supports the interaction between a learner and a learning environment. The technical feasibility of the architecture has been shown by an implementation that critically reflects on technical and educational concepts.

When performing a learning task, people need various types of information in order to monitor the progress of the task. The basis for this information is provided by what is called *indicators*. Indicators provide a simplified representation of the state of a complex system that can be understood without much training. For instance, the fuel needle of a car is an indicator that summarizes how full the tank is and how far one can drive. Without much training people understand that it is necessary to find a filling station if the fuel needle points towards the lower end of the scale. To make the appropriate decision it is not necessary to know the size of the fuel tank, the exact amount of fuel that is left in it, or about the fuel consumption of the motor. Some cars switch on an additional light, if the fuel level falls below a critical level. Such indicators focus on the attention to important facts that one could miss or ignore otherwise. The telephone bell is another example for such indicators: it indicates that someone is calling on the phone, of which one would not be aware of, unless the telephone line is checked actively. This leads to another characteristic of indicators: they help to focus on relevant information when it is required, while people do not have to bother about it most of the time.

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[1] This chapter is based on:
Glahn, C., Specht, M., & Koper, R. (2007a). Smart indicators on learning interactions. In E. Duval, R. Klamma, M. Wolpers (Eds.), *Creating New Learning Experiences on a Global Scale* (pp. 56-70). Berlin, Heidelberg: Springer.
Glahn, C., Specht, M., & Koper, R. (2007b). Processing learner profiles for smart indicators. Paper presented at the *ePortfolio 2007 Conference*. October, 18-19, 2007, Maastricht, The Netherlands.
Glahn, C. (2008). *SIRS Source Bundle*, Version 1.0.0 [Computer Software and Manual]. Available at http://hdl.handle.net/1820/1543

Actors depend on indicators in order to organise, orientate and navigate through complex environments by utilising contextual information (Butler & Winne, 1995; Weber, 2003). Contextual information on the learning process has been proven as relevant for learning support. This information stimulates the learners' engagement in and commitment to collaborating processes (Beenen et al., 2004; Ling et al., 2005; Rashid et al., 2006); it helps to raise awareness of and stimulates reflection about acquired competences (Kreijns, 2004; Kreijns & Kirschner, 2002); and it supports thoughtful behaviour in navigation and on learning paths (Van Nimwegen, Van Oostendorp, Burgos, & Koper, 2006). Despite this evidence on the role of indicators, little research has been conducted on the problem of adapting indicators to the changing needs of the learners throughout their learning process.

The research presented in this chapter investigates how to make non-formal and informal learning more attractive. The main focus is on how to support learners in their engagement in and reflection on the learning process by providing smart indicators. This chapter critically reflects on the earlier work on smart indicators: based on the concept of context aware systems (Dey, Abowd, & Salber, 1999) and the learning interaction cycle of self-regulated learning (Butler & Winne, 1995; Garries, Ahlers, & Driskel, 2002) the requirements of smart indicators are specified. These requirements are discussed in the adjacent two sections. In order to meet these requirements, the conceptual models were integrated and translated into a system architecture. Section four explores this architecture and analyses the gaps in current research on indicators related to it. The technical feasibility of the architecture is shown by implementing a prototype. The fifth section critically reflects the technical and educational concepts that were implemented into this system.

Defining indicator systems

The previous section highlighted some principles of indicators. With regard to learning technology, feedback and recommender systems meet these principles. Therefore, it is necessary to distinguish indicator systems from them. Feedback systems (Passier & Jeuring, 2004; Rieber, Tzeng, Tribble, & Chu, 1996) analyze user interactions to inform learners on their performance on a task and to guide the learners through it. Recommender systems analyze interactions in order to recommend suitable follow-up activities (Adomavicius & Tuzhilin, 2005). The objective of both system types is to affect a learner’s future activities by providing useful information. Both approaches are tightly coupled to goals or processes that are shared within a learning community. In contrast, indicator systems provide information about past actions or the current state of the learning process, without making suggestions for future actions. Having these considerations in mind, indicator systems are defined as following.

> *An indicator system is a system that informs a user on a status, on past activities or on events that have occurred in a context; and helps the user to orientate, organize or navigate in that context without recommending specific actions.*

This definition is related to self-directed and self-regulated learning (Butler & Winne, 1995; Ley & Young, 2001; Mory, 2003; Orange, 1999). In this relation it suggests that information about learner actions is supportive to learning processes because people continuously seek for indicators that help them to verify or modify their actions, tactics and strategies (Jamieson-Noel, Chu, & Winne, 2004; Weber, 2003). In that sense, indicators are facilitators of these processes and are based on the following three general principles (Dey & Abowd, 1999; Kreijns, 2004; Ley & Young, 2001).

- Indicators rely on monitoring of the learning actions and the learning context.
- Indicators have to adapt according to a learners' goals, actions, performance, outcomes, and history as well as to the context in which learning takes place.
- Indicators are responses to a learner's actions or to changes in the context of the learning process, where the response is not necessarily immediate.

Most indicators implement a static approach of providing information to learners rather than adapting to the learning process (Chapter 3). These approaches are considered as static as they follow a fixed rule-set to collect, to aggregate and to indicate information to learners. In contrast, *smart indicator systems* adapt their approach of information aggregation and indication according to a learner's situation or context.

An architecture for smart indicators

Indicators are part of the interaction between a learner and a system, which is either a social system, such as a group of learners who are supported by a trainer, or a technical system like software for computer-supported training. Chapter 2 discussed the relation of learner actions and meaningful responses for self-regulated learning. The chapter already concluded that meaningful responses depend on the context in which they are provided. This means that a smart indicator has to be aware of the context of a learner. This section describes a system's architecture for smart indicators and how to use traces of learner interactions and other contextual data for providing meaningful information in response to learning actions.

The smart indicator architecture is an application of an architecture for context aware and context adaptive systems as it has been described in Zimmermann, Specht, & Lorenz

(2005). The architecture has four layers and specifies operations on the data and information flow through a system from the learner input to the system response (Figure 4.1). The layers are the sensor layer, the semantic layer, the control layer, and the indicator layer, which were already described in detail in Chapter 2.

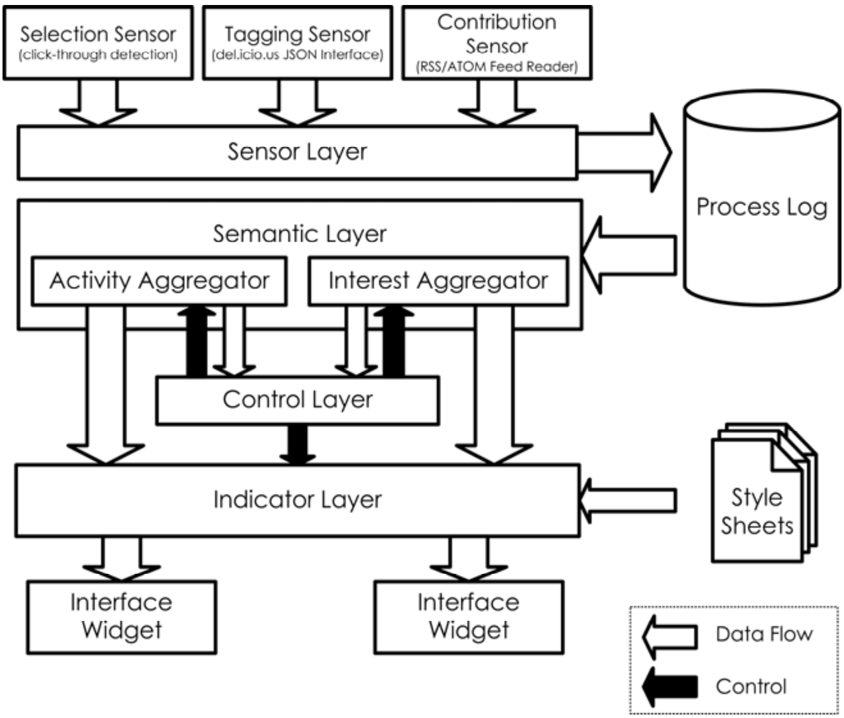

Figure 4.1: Component interaction of the prototype

Many approaches in adaptive hypermedia implement adaptation on the level of the semantic layer, while the main strategy at the level of the control layer does not adapt to the learning process (e.g., Ahn, Brusilovsky, & Farzan, 2006; Bretzke & Vassileva, 2003; Cheng & Vassileva, 2005a, 2005b; Farzan & Brusilovsky, 2005; Vassileva, 2004). In contrast, the approach of smart indicators adapts the strategies on the control layer in order meet the changing needs of a learner. By doing so, the adaptation strategies are adaptable to the different contexts of learning.

Learner and Context Modelling

With regard to the three defining principles of indicator systems, learner monitoring and learner modelling are central factors in the process of offering indicators for the learning process. The first requirement defines that indicators rely on learner and context monitoring and the second requirement defines that indicators have to adapt to the learning progress and learning context. These requirements specify that an indicator system has to develop concepts of both the learners and the learning context. Based on this information the indicator system can select appropriate information and representations of that information for a learner.

In order to identify learning processes and changes in the learning context it is necessary to maintain a history of the learner's interactions. A learner model is basically a collection of traces of past interactions with the system. These interaction footprints can be used to assess certain factors of the learning process, such as activity or interest (Dron, Boyne, & Mitchell, 2001; Farzan & Brusilovsky, 2005; Wexelblat & Maes, 1999). In the proposed architecture the learner modelling is performed in two steps. The first step is the data collection and homogenisation; and the second step is the semantic aggregation and assessment.

The system's view on the learners and learning context depends on the data that is available for interpretation. This underlying data is collected and homogenised by the sensor layer. The sensor layer accepts data coming from different sensors types and origins. The sensor layer clusters the incoming data into named sensor groups in order to maintain and organise the incoming data. Within a sensor group each data set contains the same type of information. For instance, in the scenario of the design study a sensor collects data about which tags were used by a learner. This data may originate from the use of tags for social book-marking or web-logging; or from detected selections of links in the system's user interface. From the system's perspectives, this data belongs to the same class and is therefore organised within the same sensor group in the learner's process-log.

The sensor data is stored in a database. This database organises the incoming data in alignment with the activity notation of the IMS Learner Information Package specification (IMS LIP) (Smythe, Tansey, & Robson, 2001). IMS LIP activity information allows collecting process information on learner activities within a learning environment which is similar to a log-file.

Although the described approach of learner and context modelling is suitable for the scenario of this study, this approach is limited to social and temporal contexts. The given approach excludes spatial contexts that are defined by special sensor measures that are independent from learner actions. Examples for such independent data sources are GPS sensors or thermometers. While being aware of possible limitations, spatial sensor information was excluded from this research.

Defining adaptation strategies

On the semantic layer the sensor data in the process-log is enriched. The definition of aggregators is defined as rule-sets. For these rule-sets IMS Learning Design (IMS LD) level B conditions (Koper, Olivier, & Anderson, 2003) were used as an anchor. However, IMS LD conditions support neither data sets nor arrays in properties, while the sensor information in the process-log is available as data-sets. By extending IMS LD conditions with simple set operations such as "sum", "average" or "range" it was possible to define the aggregators by using a well tested approach. The aggregators are referred to through unique names and are exported as global properties of an IMS LD monitoring service.

The adaptation strategies on the control layer are defined as IMS LD activities. IMS LD activities are defined by pre- and post-conditions and a set of resources that should be used during the activities. For defining an adaptation strategy the output of the aggregators of the semantic layer are used to define pre- and post-conditions for a part of the strategy. The aggregators that are used while a strategy is active are referred as resources of the IMS LD activity.

A prototype for smart indicators

In order to develop a better understanding of supporting strategies of the learning interaction cycle a web-based prototype of smart indicators has been implemented (Glahn, 2008). The prototype integrates smart indicators into a community system. This system combines learner web-logs with del.icio.us link lists and tag clouds (delicious.com, n.d.) of the community members. The indicator provides information on the interest and the activity to the learners. It contains two core components: an interest tag cloud and an overall activity chart. To maintain these indicators the system tracks selection activities, tagging activities, and contributions. The system adapts the presented information according to a learner's activity and interest level: it provides richer information the more a learner contributes to the community. Therefore, new participants will have different information indicated than those who contribute regularly to the community.

According to the architecture the prototype has the following functional layers. A sensor layer monitors the learners' activities and collects traces of interest. A semantic layer provides two aggregators to transform the data provided by the sensors. A control layer controls the indicator behaviour according to the results of the aggregators of the semantic layer. The indicator layer transforms the information into widgets that are integrated into the user interface of the system.

Sensor Layer

The sensor layer captures sensor information on contributions, tagging activities and selections. This layer gathers and organises the interaction footprints of a learner in the community system. The prototype implements this by immediate and delayed interaction tracing. Immediate interaction tracing is implemented only for selections (so-called click-through), through which the system gathers information about requests of web-log entries or links from the link list. Data about contributions is accumulated from information feeds in the RSS2 (Winer, 2003) or ATOM (Nottingham & Sayre, 2005) format. This process is independent from a learner's activity on the user interface. Information on the collected links and comments for the community is gathered through delicious.com's RPC interface (delicious.com, n.d.). The tagging activities are extracted from the data on tag clouds that are provided from both the link lists and the learner's web-logs. A learner tags a link or a web-log entry if a tag is added to the contribution. The data collected by the different sensors is stored in a central process-log for further processing.

The prototype uses six sensors to monitor the actions and interest of the community members:

1. *Tagging sensor*, which traces the tags that a learner applied either to a link in del.icio.us or to an entry in a web-log.
2. *Tag selection sensor*, which traces those tags that were selected from a tag cloud or a tag list of an entry in a web-log.
3. *Tag tracing sensor*, which traces the tags that are assigned to web-log entries or del.icio.us links when a learner visits this entry.
4. *Entry selection sensor*, which traces the hyperlinks a learner has accessed.
5. *Entry contribution sensor*, which traces the contributions of a learner to the community.
6. *Access time sensor*, which traces the time of an interaction.

Semantic Layer

The semantic layer of the prototype provides two aggregators: an activity aggregator and an interest aggregator. The semantic layer analyses the sensor data according to a definition given by the aggregators. Different to the sensor layer, the semantic layer is not limited to organising incoming sensor data, but it uses the aggregators to *transform* the sensor data into meaningful information.

The activity aggregator selects the data from the *entry contribution sensor, entry selection sensor, tag selection sensor,* the *tagging sensor,* and the *access time sensor*. Activity is defined as the number of actions per time interval. The activity aggregator calculates the activity for a time period and for a learner or for the entire community. Additionally, the activity aggregator provides absolute or relative activity values. The absolute activity value is the total number of a learner's activities per time interval. The relative activity value is defined by the relation of the absolute activity values of a learner or the community and the best performing community member. Both activity values are provided as numbers.

The activity aggregator respects that the sensors do not contribute in the same way to the results with regard to effort, frequency and relevance. The aggregator rates contributions much higher than selections by adding a bias to the contribution activities. For example, selecting a hyperlink requires less effort than tagging some information, which itself requires less effort than contributing a new web-log entry or commenting a link in del.icio.us. It is also less likely that a learner tags a web-page or a web-log entry that has been already tagged by another learner. Thus, selections are likely to occur more frequently than tagging activities or contributions.

The interest aggregator selects data from the *tagging sensor, tag selection sensor, tag tracing sensor*, and e*ntry contribution sensor*. Interest is defined as the number of actions that relate to a tag. In other words, the more actions of a learner that are related to a tag, the higher is the interest in it.

Claypool and colleagues identified that different types of sensors have varying relevance for identifying the learners' interest (Claypool, Le, Wased, & Brown, 2001). They distinguish between explicit and implicit interest sensors. Learners show explicit interest in a topic, if they select a tag from a tag cloud, label a link using a certain tag, or contribute a web-log entry on the topic. Implicit interest is given if learners follow tagged hyperlinks, or visit web-log entries that are related to a topic.

In this context, entry contributions, tagging actions and tag selections are explicit interest sensors while tag tracing sensors and entry selection sensors are implicit interest sensors. For the interest value, explicit sensor data is of higher relevance and has therefore a greater impact on the results of the aggregator. The interest aggregator reflects this by adding a bias to the values of the implicit interest sensors. This aggregator calculates for each tag in the tag cloud the interest value, and provides a data-set of tags and interest values as a result.

The interest value provides information about the kind of interest a learner has in a topic. The prototype distinguishes between passive and active interest. Learners have passive interest in a topic if they access or tag information. Active interest is given if learners contribute comments on items of the link list and through the web-log entries. The interest aggregator indicates this information by signed interest values. A positive value identifies those topics that are of active interest, while negative values refer to a learner's passive interest.

Control Layer

The control layer defines how the indicators adapt to the learner behaviour. The prototype implements two elemental strategies. The first strategy aims at motivating learners to participate to the community activities. The objective of the second strategy is to raise awareness on the personal interest profile and to stimulate reflection on the learning process and the acquired competences. The prototype adapts the strategies according to a learner's participation to the community.

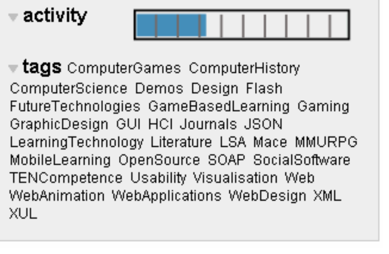

Figure 4.2: Sample indicator of the first level strategy

The typical activity for learners who are new to a community is to explore the environment in order to develop knowledge about the community's interests, activities and participants. Hence, it is unlikely that learners start contributing actively to the community from the very beginning. During this phase the smart indicator displays only the absolute activity values in an activity chart and the raw tag list of the community (Figure 4.2). With each selection of a link or a web-log entry the learner's activity status grows and indicates that each activity has its value. The community's tags are shown as a plain list of tags. This gives the learners the opportunity to explore and to understand the different topics and relate themselves to the community's interests, without receiving suggestions on the most relevant tags in the community so far.

Once a learner starts contributing links or web-log entries to the community, the control strategy selects relative activity values from the activity aggregator (Figure 4.3).

The information displays the activity of the learner and the community for the last seven days as well as for the previous seven days. This adds a competitive element to the indicator: learners see their activity in relation to the average community member and the best performing one. Additionally, it allows the learners to assess the changes of their activity levels from one week to another. For motivational reasons, this is not applied before a learner starts contributing, because contributions have a greater impact on the average activity value than selection activities have. Therefore, it is difficult for non-contributing community members to reach the average activity level, whereas the bias on the contributions allows contributing members to reach activity levels above the average level more easily.

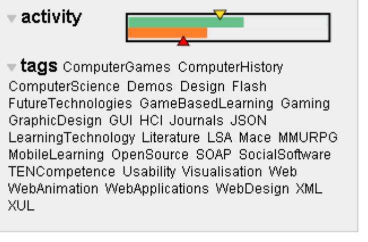

Figure 4.3: Indicator of the second level strategy

After ten web-log entries, the tag cloud starts to display the learner's active and passive interests in the tag cloud (Figure 4.4). A large number of contributions mark the end of the exploration phase. From this point in time trends of a learner's interest in different topics become accessible. Therefore, the third level control strategy uses the activity aggregator as well as the interest aggregator. By highlighting the interest in the different topics to the learners, the learners are enabled to identify the most beneficial topics of the community for their own learning process. This stimulates the awareness of concepts and their relations to the community activities.

Indicator Layer

The main purpose of the indicator layer is to embed the values selected by the control layer into the user interface of the community system. The indicator layer provides different styles of displaying and selects an appropriate style for the incoming information. To display information, the indicator layer of the prototype uses style-sheets to transform the data provided by the control layer into a learner accessible form. Depending on the style sheet the indicator layer generates an image or a widget.

For the prototype two graphical indicators and one widget indicator are defined. One graphical indicator is used during the first level of the control strategy. This indicator shows the amount of activities for the last seven days. The indicator has ten scales. Kreijns (2004) suggests using logarithmic scales to give early steps a greater visual impact. This scale was used for the scales of the activity indicator: the first seven levels represent each three item accesses; the eighth scale represents 21 item accesses, the nine levels in the middle represent 50 accesses, and the last part of the scale represents 200 accesses. This assures a high visible impact of early interactions, while the activity bar is difficult to fill by active learners as Figure 4.5 shows.

Figure 4.4: Indicator of the third level strategy

The second control strategy uses a different graphical indicator. It displays the activity in comparison to the average community member. The maximum value of the scale used by this indicator is that of the most active community member (Figure 4.6 (a)). The upper bar indicates the relative activity of the learner for the last seven days. The lower bar indicates the activity of the average community member during the same time period. Additionally, the indicator has two arrows. The upper arrow indicates the learner's activity for the previous seven days, whereas the lower arrow indicates the average community activity during that time. If a learner is the most active community member, a star is added to the end of the activity chart (Figure 4.6 (b)).

Figure 4.5: Different stages of the initial activity indicator

At the third level of the control strategy, the indicator layer provides a tag cloud widget for displaying the interests of a learner. In principle this widget is a list of hyperlinks. The tag cloud indicates higher interest values for each topic as the bigger font sizes of the related tags. For those tags that were of passive interest, the tag is set in italics. Figure 4.4 shows a tag cloud for an active learner.

Figure 4.6: Different activity visualisations of contributing community members

Conclusions

This chapter discussed a first prototype for smart indicators. Its implementation is based the principles of the learning interaction cycle and context aware systems. The prototype serves as a proof of concept for the feasibility of implementing the architecture for smart indicators in a non-formal learning environment.

Part II

Design Studies

Chapter 5
Visualisation of interaction footprints for engagement in online communities[1]

Contextualised and ubiquitous learning are relatively new research areas that combine the latest developments in ubiquitous and context aware computing with educational approaches in order to provide structure to more situated and context aware learning. The majority of recent activities in contextualised and ubiquitous learning focus on mobile scenarios, with location as the primary contextual dimension. However, the meaning of context aware learner support is not limited to location based solutions, as it is highlighted by the educational paradigms of situated learning and communities of practice. This chapter analyses learner participation as a contextual dimension of adapting graphical indicators of interaction data for engaging and motivating learners in participating and contributing to an open community. The analysis is based on interaction data and interviews with participants in a nine weeks study, during which the effect of two indicators on the engagement of the participants in the group activities has been compared. The trend of the results supports the presumption that the learners' perception of their activity visualisations is context dependent. It has been found that more engaging visualisation also polarised the participants in this group: while contributing participants were attracted to contribute more to the community, non-contributing participants were distracted by the same visualisation.

Contextualised and ubiquitous learning are relatively new research areas that combine the latest developments in ubiquitous and context aware computing with educational approaches in order to provide new forms of access and support for situated learning. The majority of activities in contextualised and ubiquitous learning focus on mobile scenarios, in order to identify the relation between educational paradigms and new classes of mobile applications and devices (Naismith, Lonsdale, Vavoula, & Sharples, 2004). However, the meaning of context aware learner support is not limited to mobile learning scenarios by default. The educational paradigms of situated learning and communities of practice (Lave & Wenger, 1991) highlight the need for contextualisation of informal learning, particularly where the learning activities are

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[1] This chapter is based on:
Glahn, C., Specht, M., & Koper, R. (2009a). Visualisation of interaction footprints for engagement and motivation in online communities. *Journal of Educational Technology and Society*. (Accepted for publication)
Glahn, C., Specht, M., & Koper, R. (2008a). Visualisation of interaction footprints for engagement and motivation in online communities – results of first interviews. In M. Kalz, R. Koper, V. Hornung-Prähauser, & M. Luckmann (Eds.), *Proceedings of the 1st Workshop on Technology Support for Self-Organized Learners* (pp. 29-43). June, 2-3, 2008, Salzburg, Austria. Available at http://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS/Vol-349/glahn.pdf

related to the workplace. In these scenarios learning processes are often unstructured, unguided, and sometimes even unintended.

Chapter 3 analysed the potential of contextualised visualisations of interaction data for supporting informal learning. These visualisations are called *action indicators*. They are called *smart indicators*, if the visualisation follows rule-based adaptation strategies (Chapter 3, Chapter 4). Such indicators may help actors to organise, orientate, and navigate through environments as well as reflecting on their actions by providing relevant contextual information for performing learning tasks, informally.

The purpose of this chapter is to identify variables and conditions for selecting and adapting visualisations of "interaction footprints" (Wexelblat & Maes, 1999) in order to facilitate context sensitive learner support in informal learning. Such learning usually takes place in unstructured environments, where *unstructured* refers to the lack of pre-defined roles and instructional designs. In these environments learners interact at different expertise and activity levels in changing or implicit roles. The footprints of user interactions can be used to determine the current context of a learner (Zimmermann, Specht, & Lorenz, 2005) by defining rules for the boundaries of each context.

In order to evaluate the benefits of indicators for learning, an adaptation strategy for visualizing interaction footprints in team.sPace has been proposed in Chapter 4. It was necessary to evaluate the indicators of the adaptation strategy regarding their supportive effects and their contextual boundaries, because the design of the adaptation strategy is based on basic presumptions that were sound from the perspective of prior research but could not be sufficiently grounded on prior empirical evidence. This chapter reports on the findings of a first design study on the contextual boundaries regarding the level of participation and analyses if the proposed indicators are suitable for engaging learners in participating and contributing to a community. This design study is a qualitative exploration for the design principles for contextualised learner support and focuses on the presumptions made for the adaptation strategy.

The following sections in this chapter report on this evaluation. The next section discusses the conceptual background of this research. This section compares and links psychological models and educational concepts with the findings of research on technology enhanced learning. The third section links the concepts to identify the gap for further research. This gap is used to set the question for research. The fourth section describes the setting of the evaluation. In this section the team.sPace system is introduced and the set-up of the indicators is explained. The fifth section links the research question and the setting towards the four presumptions that were analysed by the present study. The method of analysing the setting regarding the given presumptions is given in the sixth section. The seventh section reports the results of the automatically collected interaction footprints and the results of the interviews with participants. Finally, section eight discusses the results regarding the implications for the research questions.

Conceptual background

This chapter combines the feedback and the situated learning pillar that are discussed in Chapter 2. The context framework for situated learning is used to analyse the effects of interaction footprint visualisations on self-regulation processes of self-directed learners. With respect to information visualisation, the three concepts waylay, stigmergy, and social affordance as well as the related approaches can be explained by the model of Butler & Winne (1995). They all provide external responses on the learners' actions, which can be used for self-assessment and self-regulation. It is also possible to associate each approach to one of the contextual dimensions of Lave (1993) and Wenger (1998). However, similar to other visualisations of interaction footprints, these approaches were not analysed regarding their situated effects that were assumed in Chapter 4.

Motivation for research

Although there is some evidence that context is a critical factor for learning, the related research on technology enhanced learning has not analysed if learner support is context dependent. Therefore, it is not possible to infer from prior research, how contextualised visualisations influence engagement and reflection in informal learning. This gap in research leads to the question that indicates the motivation for research of this chapter: *what is the effect of interaction footprint visualisations in different contexts?*

Regarding this research question, the main research interest is if waylay and social affordance are dependent to the participation level of participants of online communities. Therefore, the participation has been chosen as the contextual dimension. For evaluating the initial adaptation strategy the levels of participation are distinguished as contributing and not-contributing. This chapter focuses on the ways of how indicators affect the engagement of the participants while using team.sPace (Chapter 4). Hence, the following question is the guiding line for the present research: *what are the effects of interaction footprint indicators on the engagement of participants within a community information portal, depending on their level of participation?*

Setting

team.sPace

The main research question was approached by a usage analysis of the team.sPace system (Chapter 4). This analysis is based on the data of a nine week lasting design study within a research department at the Open University of the Netherlands. team.sPace is a group information portal for online communities of practice, which jointly form a larger learning network (Koper et al., 2005). Each community in team.sPace is built around the topics and the interests of their participants. The participation in team.sPace is open and people can register and set their personal information as they would do, if they were using any other social-software platform on the web. Figure 5.1 shows a typical view of team.sPace for an authenticated user.

The information presented in team.sPace is aggregated from the participants' web-logs and social bookmarks from delicious.com. The system aggregates the information from different services using information feeds. This allows the participants to use their tools while contributing and sharing information. In order to participate, the participants had to register and add the URLs of their personal services to their user profile in team.sPace. After registering the preferred service URLs, team.sPace started collecting information from these services. team.sPace limits the aggregated information to public resources that have been "tagged" by the participants. Private or non-tagged resources are ignored.

The front-end of team.sPace presents the aggregated information in three columns. The left column displays the latest social bookmarks, the middle column displays the latest web-log contributions, and the right column presents the tag cloud of the community. The separation of different contribution types is based on the different pace of the two information streams. While social bookmarks are frequently added, writing web-log entries requires more effort. If both resource types would be presented as a single stream of information, web-log contributions will hardly receive any visibility in the community. While the first two columns contain the recent activities of the community members, the tag cloud displays those tags that are shared by them and provides an impression of the community's global interests. Besides the presentation of community interests, the tag cloud serves also as a navigation tool, through which participants can apply filters to the other columns' content.

A small information indicator extends the basic functions. The visualisation of the indicator displays the recent activity of the participant. The information shown is based on the participant's recent contributions, the visits to the portal, the number of filters that were applied, as well as the contributions, which were accessed by the participant through the portal. This indicator takes up the concepts of social proximity (Erickson, 2009) and group awareness (Kreijns, 2004; Kreijns & Kirschner, 2002).

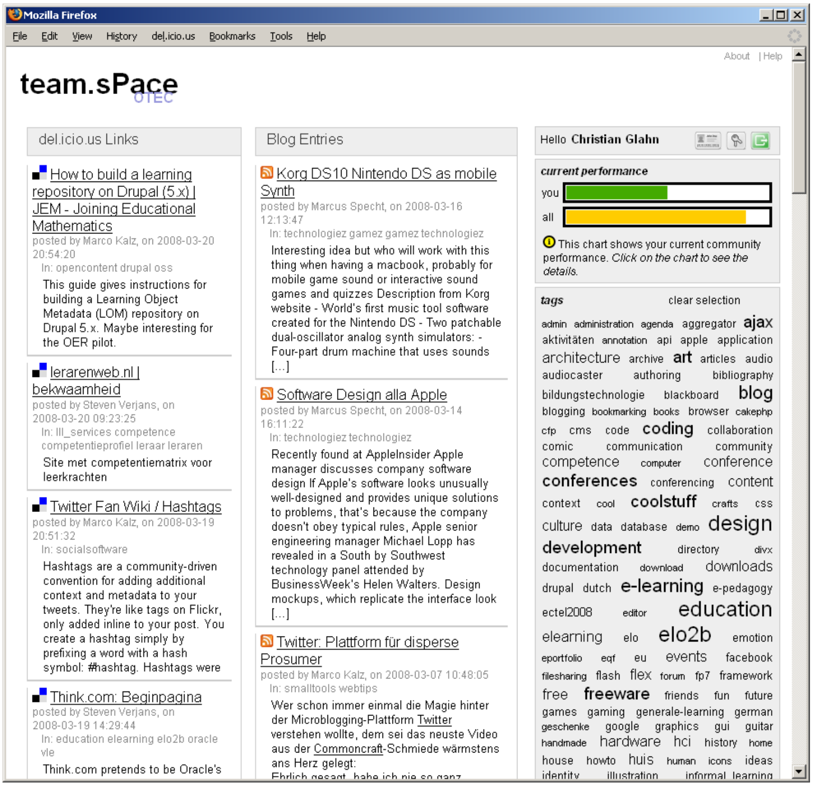

Figure 5.1: team.sPace screen for an authenticated user

Setting of the study

Two information indicators were provided for analysing the influence of context on the perception of interaction footprint visualisations. Each participant was randomly assigned to one indicator group during registration time. Apart from the different indicators all participants had access to the same instance of team.sPace.

The first indicator was an activity counter. It displays interaction footprints of a participant. Each action of a participant is counted; and all actions have the same impact on the visualisation. The activity is visualised in a horizontal raster bar-chart (Figure 5.2). This chart does not grow homogeneously with each action, but a participant has to "earn" each field with a pre-defined number of actions. With an increasing number of activated fields more actions are required to complete a field, similar to the logarithmic activity scale that has been used by Kreijns (2004).

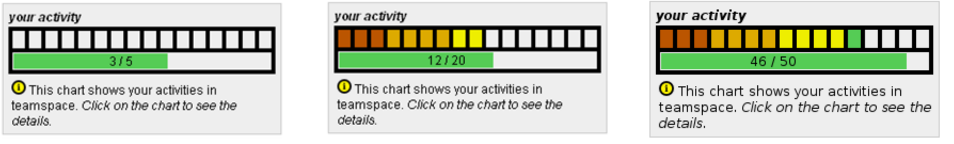

Figure 5.2: Activity counters after 3, 72, and 196 actions

The second indicator is a performance chart. This indicator is different to the first indicator in three ways. Firstly, it values the different activities by assigning activity points for each action. This means that the actions have a different value for the activity of the participant. For example an entry on a web-log is worth ten points, whereas selecting a link is only worth a single point. Secondly, the activity is not displayed in absolute terms, but relative to the activity of the most active participant in the group. Finally, the indicator integrates a second bar, which charts the same information for the average participant of the community. The performance indicator is shown in Figure 5.3.

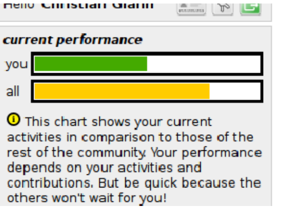

Figure 5.3: Performance indicator in action.

Both indicators have a time constraint. The displayed information presents only the activity of the last seven days. This hinders participants for piling-up actions and keeping their status while being inactive. Furthermore, both indicators provide the participants detailed information of the underlying data. The participants can access the details by clicking on the indicator. This action opens a small window that presents the sources and the values in detail, which were visualised by the indicator. This assures that the participants know what is displayed by the indicator.

Research questions

The design study intended to analyse visualising interaction footprints in relation to engagement and motivation at different stages of the learning process. Based on the considerations on self-regulated learning and context adaptation in Chapter 2 and the background section of this chapter, four research questions were formulated for this design study.

1. Is the activity counter stimulating the engagement of non-contributing participants?
2. Will contributing participants ignore the activity counter after an initial phase of using team.sPace?
3. Does the performance indicator stimulate engagement and motivation in participating in the environment for contributing participants?
4. Is the performance indicator distracting for non-contributing participants?

The four research questions refer to the adaptation strategy that has been proposed in Chapter 4. This adaptation strategy argues that non-contributing participants should receive information about their action on team.sPace in a way that is not competitive, while contributing participants receive information how they relate to others in the group. The purpose of this separation was to allow non-contributing participants to build relations to the community and to start contributing, without being distracted by strong performing participants.

Method

In order to come as close to the learning processes within a community of practice among knowledge workers, the study has been conducted with the participation of selected researchers of the Open University of the Netherlands. This group of scientific "knowledge workers" was selected to identify the design principles for supporting incidental learning processes in collaborative information organisation. The invited participants were selected according to the similarity of their research topics, while previously these persons were not collaborating intensively with each other. All researchers within the group have the joint research interest of supporting lifelong competence development through web-based technologies. This selection has been made to achieve personal benefits for the information sharing by using team.sPace. Prior to the study, the group used neither an integrated environment for sharing web-resources and web-blogs nor similar tools for other types of resources.

14 persons volunteered in the team.sPace study over a period of nine weeks. During this period the participants should set team.sPace as the starting page of their web browser. For taking part in the study, the participants had to register on the team.sPace website. During the registration, the participants were automatically assigned to one of the indicators. In order to guarantee to have about the same number of participants in each group, the selection algorithm assigned the participants alternating into the two groups.

Once registered the participants were able to authenticate to the system. The indicators were only available to authenticated users. During the observation period all actions of authenticated visitors were stored in a database. This action logging was used to aggregate the information for the indicators, as well as for the analysis of the user activities after the observation period. The recorded information included the access of the team.sPace website (visits), the access of resources (reading actions), filtering using tags in the tag cloud, social bookmarking, and web-log contributions. Because bookmarking and contributing web-logs were actions that were performed not within team.sPace, contributing participants could be active, even without visiting team.sPace directly.

Regarding the research questions the visits to the portal are relevant, because the actions are directly linked to the visibility of the indicator. In terms of the interaction footprints recorded by team.sPace, engagement is translated as *more actions per visit at the system's portal*. The other actions can be considered as indicators for the engagement of the participants. Therefore, the relation of the visits with the other actions is analysed.

For getting also a qualitative impression of the participants' experience, six participants were selected for face-to-face interviews. Three participants of each group were interviewed. In each group one participant contributed both bookmarks and web-logs to the community, one contributed only bookmarks, and one did not contribute at all. The interview partners were selected according to their frequency of using the system, their user type, and the treatment that they have received. All interviews were semi-structured and were between 20 and 30 minutes. During the interview the participants were asked to reflect on their use of team.sPace, about the parts of the system, which they liked and disliked, and on their impression of the indicator that was available to them.

Results

Of the 14 persons who registered themselves to team.sPace 7 participants were assigned to the performance indicator and 7 were assigned to the activity indicator. Five participants registered their research web-log in team.sPace; 8 participants registered their nick name for delicious.com. All participants who contributed their web-logs also contributed their delicious.com bookmarks.

Out of the 14 participants 4 stopped using the system directly after registration, of which 1 participant was assigned to the performance indicator. Another 2 participants were excluded from the evaluation, because they registered and defined the contributing services, but never visited the system afterwards. After this cleaning of the participant information, 4 participants were assigned to the performance chart and 4 participants had access to the activity counter.

The contributing participants posted 549 bookmarks and 48 web-log entries over the period of the study. During this period the team.sPace portal has been visited 232 times by the participants. The participants followed 153 times a link to a contribution and used 140 times a tag of the tag cloud to filter the information on team.sPace.

Interaction footprints

Due to this small number of participants, the data from the user tracking can get only used to highlight some trends that were observed during the study. However, the trends can only be seen in the context of the interviews that are discussed later in this chapter. This is relevant because this chapter argues on the grounds of qualitative information, drawn from the user tracking that is presented below.

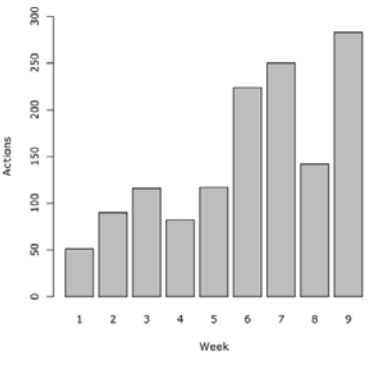

Figure 5.4: Weekly user activity

When analysing the activities over time, it shows that the number of activities is increasing throughout the study (Figure 5.4). If the actions are separated with respect to the groups that used the different indicators, it is remarkable that the majority of the actions have been performed by the group who was assigned to the performance chart, whereas the participants in the group that was assigned to the action counter there was constantly less active during the same observation period (Figure 5.5).

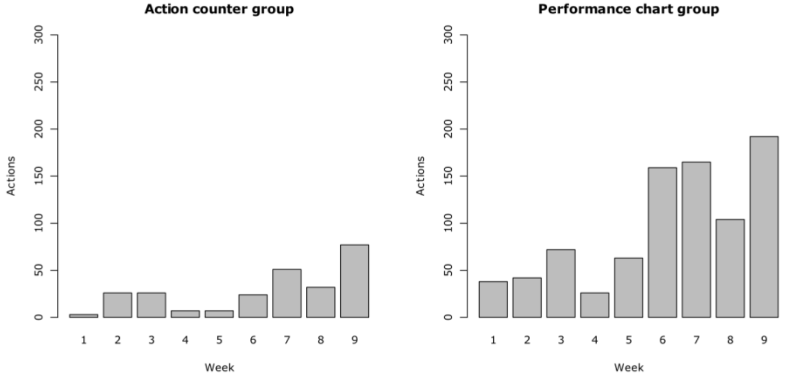

Figure 5.5: Absolute weekly activity by indicator group, excluding visits

Given this difference in user activity, it is analysed if this difference can also be observed with respect to visits on the portal. However, this was not the case because both groups had similar visiting patterns (Figure 5.6). In other words, the participants of both groups used team.sPace in comparable ways, regardless to which indicator they were assigned. More importantly, the visits cannot be related to the activity of each group.

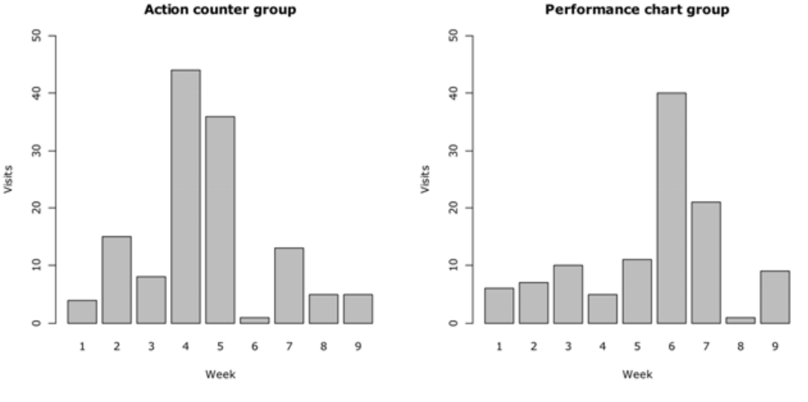

Figure 5.6: Absolute weekly visits by indicator group

For the participants who were assigned to the performance chart it is found, that the increase of activity was entirely caused by the contributing participants of that group.

Interviews

After the end of the observation period, six participants were selected for interviews. Each interview partner was asked the same three questions that are listed in the method section.

All interviewed participants replied on the first question about their general use of the system, that they frequently visited the portal, but they admitted that they did not use it as a start-up page of their browser. Instead they visited the page when it suited their working schedule. In these cases they checked what the other participants were bookmarking or posting on their web-logs. Nevertheless, they followed links only, if its abstract was interesting.

The interviewed participants reported that they liked the content organisation of team.sPace for providing a quick overview of the topics the other group members were dealing with. The participants that were contributing social bookmarks and web-logs reported that through team.sPace they started to estimate features of the external systems that they used prior to this study. An example of such experiences was the ability to comment bookmarks in delicious.com. Although adding notes and comments to bookmarks is an integral feature of all bookmarking systems, it is rarely used by default. However, in a group context, the comments can be used to highlight special features of a URL that is relevant to the community. Another example was provided by two participants: they reported that they learned about the value of social bookmarking when it is used within a group. One participant mentioned realising this as a surprise, because the participant used delicious.com for some time before the launch of team.sPace.

With regard to the general use of the system, the participants who received the performance indicator were also focussing more consciously on the quality and quantity of the contributions of the other participants. One contributing participant was complaining about link "stealing", when others bookmarked links that were previously posted by that participant on team.sPace and – from the perspective of that participant – received performance points for that. The other contributing participant was contributing only social bookmarks and mentioned that the "bloggers" were "ruining" the performance by posting three or four postings almost simultaneously.

For the participants from the activity indicator group none of the interviewed contributors mentioned their recognition of such dynamics on team.sPace during the interviews. The participants of this group reflected more about their experiences with the usability and the interface functions of team.sPace.

All interviewed participants reported that they disliked the content browsing feature of team.sPace. They found the collaborative tag cloud little helpful to find the contents they were looking for. One participant reported that it was not possible to find a contribution via the tag cloud, although the participant remembered that the entry was on team.sPace. The participants would have also liked to see the tags that were related to an entry. Furthermore, the participants were requesting a peer information feature, which provides a link to the participant's web-log, a link to the bookmarks on delicious.com; user based content filtering, or the tags that were used by another participant. Finally, the authentication procedure was not well received by the participants.

Regarding the question, how the participants experienced the indicators that were displayed to them, the two groups responded very differently. Those participants, who saw the activity indicator, responded that they checked their indicator at the beginning of the observation period, and used it for finding out how the indicator responds to which interactions. Two within this group even “admitted” that they “tricked” the system to gain more points. However, for all three participants of this group the indicator quickly lost its attraction and all three participants used team.sPace mainly as a news portal for the group, and in case of the contributors they contributed at their own pace. The participant, who was contributing bookmarks and web-log entries, stated that the indicator was “irrelevant for visiting” the portal.

The group that received the performance indicator answered differently. At the beginning of the observation period all three participants reported similar to the first group that they were playing around with the system in order to get familiar with the impact of their activities on the indicator. Because the underlying aggregator weights the different activities, it is more challenging for non-contributors to keep their performance up with the group. The non-contributing participant of this group reported this experience as “frustrating”, because the “bloggers” and “taggers” get all the points while the own activity chart hardly took off. In this particular case this frustration lead to a counter reaction: the participant created a new delicious.com account and posted a few links in order to see their impact on the performance. After the short reaction phase the participant did not contribute any other resources.

The contributing participants perceived the performance indicator more positive and connected it to the challenge of keeping up and outperform the community. In the interview both participants even asked if the indicator was displaying random information, because sometimes they estimated their performance better than what the indicator displayed. Nevertheless, both participants managed to become superior to the group and gained a maximum peek on the chart. According to the participants, this was very satisfying. The participant who contributed only bookmarks via delicious.com made this even a personal objective, which was reported as "pretty challenging" because of the random "waves" of web-log postings. Both participants reported that they followed the dynamics of the contributions carefully, as they related them to their impact on the performance indicator. Besides this generally positive connotation, both participants also mentioned that while they were "underperforming" the indicator was a constant reminder. The participant who contributed both bookmarks and web-log entries, reported "high pressure" in those cases where the personal performance chart was dropping and there was no time for new contributions due to other obligations.

Discussion

The results of the observation provide some insights regarding the research questions for the design. With this regard, the combination of the analysis of interaction footprints and the results of the interviews indicate a trend. This trend is related to the different effects of the two indicators on the engagement of the different groups that were reported in the interviews. For initial validation of the research questions, the interviews need also to be in line with the interaction footprints of the participants.

The results do not allow answering the research questions 1 and 4, because in both cases it was not possible to attract enough participants. In case of question 4 only the interview with a non-contributing participant in the performance chart group suggests that this research question might be positively answered with a larger user group. A similar suggestion cannot be made for research question 1.

While both groups were initially attracted by understanding the relation between their activities and the visualisation of the indicator, after the initial phase of using the system, the participants that were using the activity counter were less engaged with the group. Instead their responses focussed more on the general functions and usability of team.sPace. Particularly the responses from the contributing participants support the second research question.

The responses of participants from the performance indicator group had a greater emphasis on recognising the group dynamics with a strong relation to valuing mechanisms of their activities related to team.sPace. With that regard, the responses of the contributing participants are in line with research question 3.

The interaction footprints partially support these conclusions. Particularly, by relating the visits and the overall activity of the participants, the interviews are in line with the research questions 3 and 4. The presumption was that contributing participants will be more engaged in contributing to the community if they are exposed to the performance chart. I.e., they should perform more actions per visit than other participants of team.sPace. This is supported by the interaction footprints of the participants as Figure 5.7 illustrates.

Figure 5.7 shows the relation of visits to team.sPace and all other actions per participant. This diagram shows that all three contributors who were exposed to the performance chart performed relatively more actions than the three contributors who saw the action counter. This diagram also shows that although the performance visualisation was reported as discouraging by the non-contributing participant, this participant was more active than the contributing actors of the group that saw the action counter.

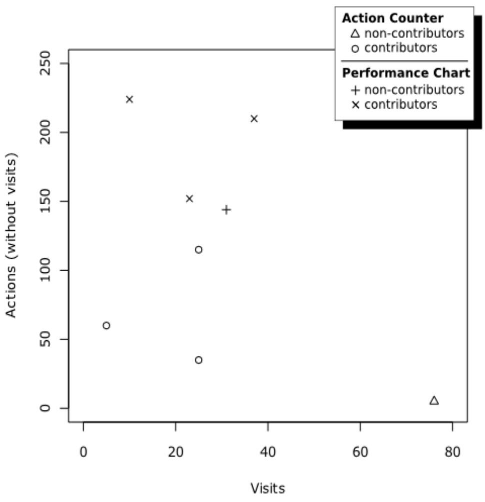

Figure 5.7: Visit to action relation per participant

The findings that are in line with the research questions 2 and 3 suggest that social affordance of interaction visualisations is sensitive to the level of *participation*. Although the empirical evidence provided by the data of this study is limited, the finding is of interest for research in two directions. Firstly, "participation" is suggested as a contextual dimension, as it was initially proposed by Lave (1993). Secondly, within their limitations the findings indicate that providing a standard visualisation of interaction footprints to all users does not meet the needs of all users in the same way. The effects of a visualisation might be positive for some users, but this is not guaranteed for all users.

As the relations between context dimensions and factors of Lave (1993) and Wenger (1998) predicted, the findings of this study suggest that the participants in the performance chart group were more sensitive towards the social dynamics and topics within team.sPace. These reports are interesting because the participants did not use the portal more frequently than other participants and did not spend more effort in studying the contents on team.sPace. This might be a side effect of *playing the system* that was reported by the participants of the performance chart group. Such playing appears to have positive effect on the participants' reflection on contents and social dynamics. This finding is relevant for supporting self-directed learning for two reasons: firstly, the participants reflected more on their social context and contextualized their activities to the community; secondly, the indicator itself contains no content related information and provides only limited information about the social dynamics. This can be related to the presence of the indicator, because all other information was the same for all participants of team.sPace. Future research will have to focus on this effect more thoroughly.

Lessons learned

This chapter analysed two different visualisations of interaction footprints regarding their effects on the engagement of participants in an online community portal. The goal of this qualitative study was to identify variables and conditions for selecting and adapting visualisations of interaction footprints in order to facilitate context sensitive learning support in self-directed and incidental learning. For this purpose the visualisations were embedded in a setting that was used in an initial design study. This setting was in use for nine weeks. To understand the effects on the different user groups, the interaction footprints of the participants were analysed and selected participants were interviewed about their experiences with the system.

The chapter compared the results of the user actions with their interviews, in order to identify if the level of participation can be used as a dimension for contextualisation, as it has been suggested by prior research. As expected for an initial design study, the results do not provide hard evidence. However, the trend of the results supports the presumption that the learners' perception of their activity visualisations is context dependent. Moreover, more engaging visualisation seems to polarise the participants in this group: while contributing participants were attracted to contribute more to the community, it appeared that non-contributing participants got distracted by the same visualisation.

From the results of this qualitative study it can be suggested that the concept of social affordance is context dependent. With regard to information visualisation this implies that the same visualisation can influence learners differently, depending on their level of participation. This supports the initial research question for the design of the adaptation strategy.

Chapter 6
Implications of Writing, Reading, and Tagging on the Web for Reflection Support in Self-directed Learning[1]

The use of tags as user generated meta-data on the web as well as the visualisation of tags in tag clouds have recently received a lot of attention in research and practice. The main focus of prior research lies on indexing and accessing content for learning, but not how tags and tag clouds can be used for supporting the actual learning process. This chapter focuses on supporting reflection of learners by using different presentation approaches of user generated meta-data for reflection support. Previous research has found that implicit interest expression can be a valuable source for reflection support. Visualising implicit or "tacit" interest in tag clouds could help learners to understand the connections of their content related activities to the tags that are assigned to the content. For grounding this potential in the social practice of using tags in teams and small communities, this chapter analyses the different uses of tags of the participants of the study that was presented in the previous chapter. This analysis looks at the personal level at tagging related activities of the participants during the three month that they worked with the system. Therefore, this study focuses on the social practices of using tags explicitly and implicitly, particularly with regard to social navigation of teams and small communities, relations of implicit and explicit interest in tags, and usages of tags on different participation levels. The findings on these dimensions of the social practice of using and sharing tags in groups help to develop a better view on the requirements of providing reflection support in self-directed and incidental learning.

The use of tags as user generated meta-data on the web has recently received a lot of attention in research and practice. A large number of scientific contributions focus on community driven creation of meta-data (Heymann & Garcia-Molina, 2007; Hsieh, Lai, & Chou, 2006), or on improved accessibility of contents through this kind of meta-data (Ishikawa, Klaisubun, & Honma, 2007; Michlmayr & Cayzer, 2007). The majority of these contributions exploit the explicit use of tags for these purposes. Only few publications have so far focussed on the relations between the explicit and implicit use of tags with contributions, search queries, and information access (Farzan & Brusilovsky, 2005; Millen & Feinberg, 2006). Particularly, contributions on applying tags in the

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[1] This chapter is based on:
Glahn, C., Specht, M., & Koper, R. (2008b). Implications of writing, reading, and tagging on the web for reflection support in informal learning. In M. Specht & P. Dillenbourg (Eds.), *Times of convergence, technologies across learning contexts* (pp. 110-121). Berlin, Heidelberg: Springer.

educational domain basically address the value of this kind of meta-data for improving access to relevant content. This research addresses the acquisition of knowledge that is already available in an operational form to the learners. The knowledge that is operational in learners resembles their usage of certain tags to label information, or their ability to translate their needs for information into appropriate search terms. From an educational perspective this covers only a limited part of learning processes, because these processes include – amongst others – reflection activities. Reflection is a fundamental learning activity and is needed to articulate, express, and apply knowledge appropriately (Schön, 1983).

Figure 6.1: team.sPace tag cloud (detail view)

This chapter addresses the need of supporting reflection of self-directed learners. The research is particularly interested in using different presentation approaches of user generated meta-data for reflection support. A common example of such a presentation is a *tag cloud*, in which the tags are not only listed, but their frequency of use is represented in the display size of each tag i.e. tags are of a larger size if they were frequently used than less frequently used tags (Figure 6.1). The frequency of a tag is therefore *encoded* in its display size. Chapter 4 already suggested that different forms of information encoding in tag clouds can stimulate and support reflection on learning processes that are embedded in other activities. How this can be achieved for stimulating and supporting engagement in social interaction was also outlined in the previous chapters. Furthermore, the theory presented in Chapter 2 suggests that reflection support could be dependent to the context in which learners are active. However, these approaches of reflection support are to this stage conceptual outlines, which require a better understanding of the social practice of the contexts in which tags are applied.

One aspect of supporting reflection by using tag clouds in collaborative learning settings lies in bringing the attention to a user's interests in different tags in relation to the interests of the larger group. Given the goal to support users in recognising their tacit knowledge, the interest in tags is not necessarily restricted to the explicit use of tags, but can be extended towards the implicit usage of tags. So far only limited research has reported on implicit interest expressions and the relations of interest and social practices in online communities. Therefore, this chapter analyses the use of tags not only while contributing and searching content, but also while reading the contributions of other users. This analysis is based on the data on tag usage that has been collected from the team.sPace (Chapter 4) environment during the initial design study (Chapter 5).

Question for research

For supporting reflection in informal learning scenarios, this chapter concerns learning processes related to knowledge creation and knowledge exchange in teams or small communities. For this purpose it is necessary to develop more insights about the contributions of different user activities to information from which the user's interests can get deduced. As noted by Claypool, Le, Wased, & Brown (2001), one has to distinguish between explicit and implicit references to a user's interests. Such references are related to different types of user actions. The authors focused on understanding which user activities are relevant for deducing a user's interest. However, it has not been studied if the different user activities express the interests of a user in similar or different ways. Therefore, this chapter seeks to answer the question, if a user's *implicit* expressions related to tags provide in different information about a learner's interests than *explicit* tagging expressions do.

Explicit interest expressions are all actions that are directly related to a user's interest and provide evidence of interest. Such expression can be that a user rates a certain content, that a resource is bookmarked and tagged by a user, or if a user writes a web-log entry and categorises it by using tags. Typically, *implicit interest expressions* do not provide direct evidence about a user's interest, but support its chance. Examples for implicit interest expressions are: a user accesses a resource, the time a user spends viewing a resource, a link that is followed to a bookmark, or a user selects a tag in a tag cloud to filter content.

Understanding the hidden life of user generated meta-data is a prerequisite for any approach that seeks to bring knowledge to the attention of a user, which would otherwise remain tacit. In this case this study provides the insights if the initially drawn ideas on facilitating reflection support based on user generated meta-data are actually feasible based on the habits of real people with regard to the explicit and implicit use of tags. These insights on user generated meta-data and social navigation are useful for supporting the learners' reflection in and about action, and for leveraging the impact of knowledge management in small scale environments.

Background

Given the perspective of the three pillars of research that are discussed in Chapter 2 it is reasonable that reflection support should also follow the principles of the learning interaction cycle. Therefore, it can be assumed that user-generated meta-data such as tags helps to identify explicit and implicit interests of users, which can be used to stimulate reflection on their personal learning processes. This research has similarities to utilizing information about explicit and implicit interest of users to support their interaction with online information systems (Claypool, Le, Wased, & Brown, 2001); and with link sharing and social navigation (Millen & Feinberg, 2006).

Claypool, Le, Wased, & Brown (2001) compared implicit with explicit interest expressions in web-based content. The goal of their research was to identify if implicit expression of interest in content can be used as an alternative to explicit rating of content. The authors distinguish between explicit expressions of interest, such as rating content, and implicit expressions of interest like reading content or bookmarking content. In a pilot study different kinds of user interactions have been analysed regarding their relation to a user's interest in contents. The authors identified that not all "promising" types of interactions can be used to infer the users' interest about a resource. The findings of this study were largely confirmed by a study in the educational domain (Farzan & Brusilovsky, 2005). Although this research also focuses on user interest, it differs from this previous research in two ways. First, Claypool, Le, Wased, & Brown (2001) and later Farzan & Brusilovsky (2005) analysed the user interests relative to single resources, while the present research addresses interests regarding tags and concepts that are shared between resources. Second, this chapter analyses the conceptual differences of implicit and explicit interest, while the previous research addressed only the users' interests in resources.

Millen & Feinberg (2006) have analysed the social dimension of sharing and browsing resources on the worldwide web in an organisational context. The authors were interested, if providing social bookmarking within an organisation leads to social exchange across the organisation, or if it leads to accumulation of information, in which only parts are relevant to the individual members of the organisation. The related field experiment used the "dogear"-environment (Millen, Feinberg, & Kerr, 2006) and identified that social bookmarking stimulates social exchange of information in a relatively large organisation (Millen & Feinberg, 2006). In a way, the present research takes up these findings and investigates if they can be extended to teams or smaller organisational structures as well. Additionally, it emphasizes qualitative aspects of the social exchange that has been observed by Millen & Feinberg (2006), as it focuses on the developments of different kinds of interests that were developed through the general social practice regarding the content.

The studies of Claypool, Le, Wased, & Brown (2001) and of Millen & Feinberg (2006) do not provide any implications on context dependency of the findings, because in both cases the experimental groups as well as their behaviour were treated as homogeneous. Both studies have not addressed contextual variables that might possibly affect the interest of the individual users. Given to the findings of the previous chapter, it is not reasonable to assume that the expression of interests is context dependent.

In short, this section identified three gaps in research: firstly, research on implicit interest expressions has been focused on single resources, but not on tags that are used with several resources; secondly, social navigation was analysed in large user communities regarding the potential of this general concept of social activity for stimulating social exchange, but not regarding its application in teams or small communities and regarding its benefit for the individual participants; finally, user-generated metadata and social navigation have been only analysed from the perspective of homogeneous groups, but not as practices that are possibly connected to context.

Design decisions

Based on the questions of research and on the gaps, which were identified in the previous section, four key research questions are defined to analyse the data of this study. The first research question is regarding the implicit and explicit tagging habits of the participants.

> *I. Do participants in teams and small communities make use of social navigation if tools for link and information sharing are provided?*

This research question implies that the participants of the team.sPace study access also the resources of others, which results in social navigation in the small community. The underlying presumption is that the findings of Millen & Feinberg (2006) on social navigation of large groups and communities are also applicable in smaller groups or communities.

2. Do implicit interest expressions of the team.sPace participants replicate the community's aggregated explicit interest that is represented in the tag cloud of the system?

This research question directly addresses the overarching question for research. It has the implication that the participants' implicit interest is not biased by the tag cloud of the system. This verifies the initial presumption that the use of tags in reading and searching is not biased by visualisation of the community's tag cloud.

Two additional research questions were defined subordinate to the second question. The prior question addresses the implicit usage of tags at different levels of participation. The latter question addresses the routine participants develop in using tags, explicitly and implicitly.

3. Are the implicit interest expressions of contributing participants more focused in certain tags then the interest expressions of non-contributing participants?

This research question refers to varying interaction patterns for participants at different participation levels. It is expected that non-contributing participants tend to explore the different topics more than contributing participants. Therefore, a wider distribution of tags for non-contributing participants than for contributing participants can be expected.

4. Are participants who contribute more to social bookmarking or blogs more likely to replicate the tags they use for their own contributions also in their implicit interest expressions?

This final research question addresses the differences of perceiving tags among the groups of participants. It suggests that participants who actively contribute in blogs and social bookmarking are more aware of their interests and therefore are more focused in their reading habits than participants who are less active. This question implies that the participants' tagging habits on one side and their reading and searching habits on the other side are not independent from each other.

Method

The tagging data was collected over a three month period of using the team.sPace environment (Chapter 4) for answering the four subordinate research questions. team.sPace is a web-based community portal that allows its participants to share del.icio.us bookmarks and their personal blogs among a group of participants. The portal has three main sections: the first part contains a feed to social bookmarks, the second part contains the blog information, and the third part contains user and navigation tools, such as a tag cloud that can be used for information filtering. The team.sPace tag cloud does not contain all tags, but only those tags that were used at least by two participants or were used by a single participant at least five times. The information provided in each part of the portal, is aggregated from all participants of a group, who have registered sources to the information of the sections. While indexing the contributions, team.sPace excludes all contributions that were not tagged. This step assures that all contributions in the portal have tags assigned.

The data of the tagging behaviour is based on the initial design study was introduced in Chapter 5. The invited participants registered themselves with team.sPace and configure team.sPace in order to enable the portal integrating their contributions into a community feed. The participants could freely choose if and which information they contribute to the group. Given the types of resources this creates four user groups: fully contributing participants who contribute blogs and bookmarks, blogging participants who contribute only blog entries, delicious.com participants who contribute only bookmarks, and reading participants who did not contribute.

In addition to aggregating contributions from delicious.com and from the participant's web-logs, team.sPace traces the participants' explicit interests through the tags they assign to their bookmarks and web-log entries. Implicit interest is traced on conceptual browsing while participants click on tags in the tag cloud; and by tracking the participants' accesses of the contributions. Within team.sPace the participants can perform three different types of activities: contributing, reading, and exploring. Because all contributions in team.sPace have tags assigned, all user actions are automatically related to tags. For analysing the tagging behaviour only the user actions were tracked, but no feedback on the participants' interests was provided based on this tracking information. After the design study the explicit and implicit uses of the tags in team.sPace were analysed in four steps in order to address the research questions. At each step the explicit and implicit tagging was analysed for each participant. The individual cases are then compared within and across the "peer group". For this purpose, the statistical analyses of the individual tagging behaviours are analysed regarding possible similarities between the members of the different groups of participants.

The first step analysed the social navigation of the participants by comparing the number of explicit and implicit tags that were used by a participant. Explicitly used tags are only assigned to the contributions of a participant, while implicitly used tags could have been also assigned to contributions of other participants. By removing all tags from the list of implicitly used tags if they were used by a participant in both ways, only those tags that were assigned to the contents of other participants remain in the list. A larger number of tags in this list indicate that a participant utilised social navigation more actively.

The second step should verify that a participant's implicit interest does not simply replicate the community's explicit interest. In order to do so, it had to be shown that the participants did not simply use tags that were highlighted in the tag cloud. To prove that this does not only replicate the participant's conscious concepts the most relevant tags for explicit and implicit activities were ranked. This ranking has been calculated for the community as well as for each participant. A tag has been considered in the ranking if a participant used it at least twice. Based on these rankings the overlap of tags was calculated for the 30 most relevant tags of the participants' implicit interest expressions with the top 30 of the ranking of the group's tag cloud. This procedure has been repeated for the overlap of the implicit and the explicit interest expressions of each participant. A lower degree of overlap in both runs indicates that the implicit interest expressions in social navigation hold potential to unveil tacit knowledge and concepts.

The third step analysed if the implicit interest expressions of non-contributing participants are more random than those of contributing participants. For this purpose the relevant tags of the second step were reused. The mean frequency and the standard deviation using the relevant tags were computed for each participant. A lower average frequency and a low standard deviation mean that the tags were used more randomly by this participant. The results have been compared for contributing and non-contributing participants.

The last step analysed if active participants are more focused in their reading behaviour and align their implicit and their explicit interest expressions. The focus on the interest in tags can be defined by the relation of the number of tags that were used only implicitly with the number of tags that were used implicitly and explicitly. A higher level of tags that were use only in implicit interest expressions means that the participant was less aligned with the explicit interests. Of course, this relation is only meaningful for contributing participants, because in team.sPace non-contributing participants cannot express their interests explicitly.

Observations

Over an extended period of three months the tagging information has been collected by the initial design study (Chapter 5). During this period 847 individual tags were assigned 3068 times to the contributions. In average a contribution has 2.2 tags assigned. 326 tags or 40% of the tags can be considered as relevant to the community, as these tags have been used more than twice during the observation period, either as explicitly assigned to a contribution, or implicitly while accessing an article or while using the tag cloud. The minimal threshold of three usages per tag assures that a tag was not used once and has then been read or selected incidentally. The relevant tags were assigned 2431 times to a contribution and therefore cover 79% of the overall explicit tag usage.

365 individual tags were assigned to contributions that were read by the participants, and 133 unique tags were accessed through the tag cloud. The average contribution that has been accessed by the participants had 3.7 tags assigned. 232 tags were assigned by at least two participants to their contributions. The majority of these tags are shared among less than four participants (78%). Another 30 tags were assigned more than five times by a single participant. The tag cloud in team.sPace displayed therefore 262 tags at the end of the observation period. 159 tags were read, and 97 were accessed through the tag cloud by at least two participants. 43 tags were accessed by different participants while reading and searching.

Among the relevant tags within team.sPace several concept clusters were recognised. These clusters contain tags that reflect semantic similarities. An example of such a cluster is learning, which is reflected by the tags: "bildungstechnologie", "e-learning", "elearning", "e-leren", "e-pedagogy", "educationaltechnology", "learning_technology", "learningtechnology". The tags in these clusters were accessed very differently. Although a detailed analysis of these tag clusters would be interesting, it is beyond the scope of this study.

The range and variety of this data set allows the application of the analytical steps, which have been defined in the previous section, and draw first conclusions with regard to the research questions of this chapter. The following paragraphs report on the results of the four analytical steps.

In average, the contributing participants "reused" their tags in their implicit interest expressions 37% ($n=8$; $\sigma=17\%$). This result includes all tags that were assigned to the resources. With regard to the tags that were relevant to the group, 56% ($n=8$; $\sigma=23\%$) of the tags that were assigned to a participant's contribution, were also used in implicit interest expressions.

The 30 most frequently used tags in the participants' implicit interest expressions overlapped with the most relevant tags of the shared tag cloud in average to 40% ($n=11$; $\sigma=11\%$). The implicit interest expressions of the non-contributing participants overlapped the communities interests to a lower extend (34%; $n=3$; $\sigma=13\%$) than the interest expressions of the contributing participants (43%; $n= 8$; $\sigma=11\%$). This step has been repeated with the ten most frequently used tags of each participant. The average overlap of implicit interest expressions and the tag cloud was for non-contributing participants 20% (n=3; σ=20%), and 48% (n=8; σ=13) for contributors.

The average implicit interest of contributing participants in these tags has been expressed by 2.5 requests (n=8; σ=1.7), the average range of interest was 2 tags (n=8; σ=1.6). Compared to these results, the non-contributing participants expressed their implicit interest in average by accessing 1.6 tags (n=3; σ=0.8) with a range of 1.2 tags (n=3; σ=1.4).

With regard to the focus of interest of the participants, in average 53% of the tags were used only in implicit interest expressions (n=8; σ=20%). With regard to the participation to the group, more active participants were compared with less active ones. The threshold for more active participation was defined as a minimum of 100 tags in implicit interest expressions. This threshold created two sub-groups of each four participants. With regard to their focus of interest, the more active participants were more interested in tags, which they did not use themselves (57%; n=4; σ=11%). In comparison, less active participants were less focused on the tags, which they did not use themselves (49%; n=4; σ=27%).

Lessons learned for designing reflection support

The observations support the research question 1 that team.sPace supports social navigation in teams and small groups. The low ratio of overall repetition of explicitly used tags in implicit interest expressions (37%) indicates that the participants were interested in the contributions provided by the other participants. As for each contribution a short description is provided in the portal, the participants are more likely to access information in which they are interested. More relevant tags appeared more often (56%) in implicit and explicit interest expressions, as these tags were shared among the participants and thus were assigned to more resources. These observations suggest that tags are not only used to structure the own resources, but are also relevant for exploring interesting content of other participants. Thus, principles of social navigation also appear to apply also to smaller groups.

The results are in line with research question 2. The overlap of the most frequently used tags in the participants' implicit interest expression and the most relevant tags of the team.sPace community was relatively low. This indicates that the tag cloud affects the actual reading habits to a limited extend. This was particularly the case for non-contributing participants. However, from the ranking of implicit interest expressions it seems that all participants partially referred to semantically similar tags. This can be explained with the low sharing rate of tags, because the majority (78%) of shared tags have been shared by two or three participants. Therefore, it seems to be likely that another participant labelled similar contents with different tags. If participants access these contents, it does not necessarily mean that they are unaware of the underlying concepts.

The tendency of the results is in line with research question 3. The data indicates that the average frequency of tag usage and its deviation were lower for non-contributing than they were for contributing participants. However, the differences between the groups are too small to draw conclusions. These results imply that non-contributing participants would not need different support for exploring resources of a community than other participants. For getting more detailed insights on this question more data is necessary.

With respect to research question 4, it has been expected that participants, who contribute more actively, are more focused in their reading habits with respect to the tags they use themselves. The results did not support this expectation. Instead, the opposite was found: less active contributors appear to focus more on the tags they use, while more active participants were exploring the content to a larger extent. This finding suggests that the more active participants of the community may reflect more on the usage of tags by themselves and by the community. It appears that more active participants focus on a greater variety of contributions and to relate their choices of tags to their insights. As the observations were only focused on the implicit and explicit usage of tags, more research is needed to verify this interpretation of the data.

The initial presumption made in Chapter 4 that hiding information about the implicit and explicit interests of the non-contributing participants supports their endeavours of exploring the contributions of a community. The current findings suggest that this design decision should not be taken into account. However, the observations suggest the use of thresholds before interests are expressed, because not all tags that are used by participants contribute equally to their personal interests.

The observations of the participant's habits of creating and sharing tagged information showed that the participants used different tags to describe similar concepts. While this habit may lead to not preferable results for information standardisation it can be beneficial for supporting reflection on concepts and group activities. The observations suggest that not all tags were used by the participants to group resources, and that the resulting groupings are not necessarily reflecting a common sense in the group. This means that different participants related different tags to resources even if these tags have similar meanings. However, the slightly different perspectives of the participants might be beneficial for their personal learning process in the community environments for two reasons. Firstly, the use of tags of similar concepts might refer to subtle differences that are relevant to the community. Secondly, through the visibility of the similar concepts may support reflection on these concepts that may yield new insights for the participants.

Implications for designing reflection support

The goal of this analysis was to identify if a participant's implicit expressions of interest provide different information then the information gathered from explicit interest expressions. The findings are in line this presumption. Therefore, it can be assumed that implicit interest expressions can be used for stimulating reflection on tags or concepts of which otherwise the participants would not be aware of. However, there are two restrictions to this finding.

First, a large number of tags appear to be used for personal structuring, but seem not to be relevant to the community. These tags are part of the so called long-tail and are used only once or twice by a participant. This finding suggests that it was appropriate to exclude tags from the tag cloud if they were not shared.

Second, the observations suggest that the unknown tags of implicit interest expressions hold the potential to identify the learners' personal interests in a topic. "Unknown" tags are those tags that are assigned to accessed resources, but that are not actively used by the learners themselves. They could highlight semantic variations of concepts that a participant is already aware of, but also help the participant to develop a more coherent knowledge model of the domain. Conceptual similarity of tags and the relation to understanding of the domain knowledge outlines a possible demand of participants for being able to express the relations between the tags they use. Future research will have to address the effect of active and passive reflection on tag and concept visualisation, and develop a better understanding whether semantic similarities make a difference for the reflection process.

For the design principle of the adaptation strategy, the trends of this analysis can indicate that the differences of implicit tagging of non-contributing and contributing participants can serve as a factor for adapting a tag cloud visualisation might be wrong.

Conclusions

This chapter analysed the explicit and implicit use of tags in an open community portal. The initial idea was to visualise a participant's interests on the different topics of the community in the tag cloud of the portal. Therefore, it was expected that particularly implicit interest expressions can be used to highlight *tacit* knowledge on the participants' interests on the contributions made to teams and small communities. Such tacit knowledge is expressed implicit through interest driven activities that do neither replicate the explicitly expressed interests nor the structure of the tag cloud. Furthermore, it was expected to identify different usage patterns among the participants of different participation levels. Although the study on the usages of tags as information sources to the interests of the detected no contextual relations of the way how tags are used, this study suggests that implicit interest expressions can be used to make *new* tags of interest available to the participants.

The current study has only focused on the usage of tags by users in teams and small groups. Future work will analyse if integrating visualisations of explicit and implicit interest expressions actually stimulate the reflection on tags and concepts.

Chapter 7
A Tag Cloud for the Reflective Self-directed Learner[I]

This chapter reports on a qualitative study about the application of tag clouds for supporting meta-cognition in self-directed and incidental learning. Tag clouds are a popular and simple visualisation of the usage of free form keywords on the Internet. The study in this chapter analyses the use of the ReScope system that provides a personal tag cloud visualisation of the tags that are used at a public social bookmarking service. ReScope is based on a reflection support use case developed by the TENCompetence project. The study focuses on the types of meta-cognitive control based on reflection notes of the learners. These notes were analysed regarding the contents of the reflections as well as regarding their meta-cognitive type. The results indicate that a personal tag cloud can stimulate reflection on the tagging activity of a learner. Furthermore, it indicates that reflecting on the tagging activity is not built into the design of a tag cloud.

This chapter reports on a qualitative study about using tagging visualisations to stimulate reflection about self-directed or incidental learning activities. The term tagging is used to describe labelling of arbitrary resources found on the Internet by using free form key words – the tags. The concept of tagging has been widely adopted by many social software services in the context of the Web2.0 (Smith, 2008). Prior research (De Smet, Van Keer, & Valcke, 2008) has argued that labelling and tagging supports meta-cognitive processes in self-regulated learning. The conceptual structures that result from free labelling can be complex to understand without additional support. Visualisations of selected aspects of such structures help people to recognize and to manage this complexity (Card, Mackinlay, & Shneiderman, 1999). A tag cloud is a visualisation of tag information, in which the number of tag uses is coded into different sizes and colours of the tags. A tag cloud makes the overall structure of tagging habits visible and provides a view on the learner's personal knowledge expressions.

For supporting self-directed and incidental learning tag clouds hold some potential to stimulate reflection on concepts and learning processes. This chapter focuses on tag clouds that are based on the personal tagging information of a learner. Although such

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[I] This chapter is based on:
Glahn, C., Specht, M., & Koper, R. (submitted). A tag cloud for the reflective self-directed learner. *Journal of Computer Assisted Learning*.
Glahn, C., Specht, M., & Koper, R. (2008c). Reflecting on web-readings with tag clouds. Paper presented at the *Computer-based Knowledge & Skill Assessment and Feedback in Learning Settings* (CAF). Special track at the 11th International Conference on Interactive Computer aided Learning (ICL 2008), Villach, Austria.

visualisations do not provide valid information in terms of approved domain knowledge, they provide associative information about the learner's tags. This information can stimulate reflection because the visible tags are meaningful to the learner and allow associations to the actual learning experiences. This chapter analyses if the visualisation of a learner's tagging activity in the form of a tag cloud can stimulate meta-cognition of self-organised learners. Tag clouds are widely implemented visualisations of tagging information and can be identified with many services on the Internet. The present study analyses the types of reflection that are stimulated by a personal tag cloud that is based on the data provided by the public social bookmarking service delicious.com (delicious.com, n.d.).

Background

Tagging stands for applying free form keywords (the tags) to resources that result in user-generated metadata. Tagging is closely related to the developments in the context of the Web2.0. (O'Reilly, 2005). The Web2.0 stands for web-based services that allow their users to create and manipulate resources; that support sharing these resources with other users; and helps to build networks of peer users within the scope of the services' functions. This type of services is also referred to as social software, for which some success stories of commercial systems gained wider public attention (e.g., MySpace, Facebook, Flickr, and Twitter). Tagging has become one of the key activities of Web2.0 applications and has received some attention in research and practice. It has not only been integrated by a large number of social software but is also a feature of famous e-commerce services, such as Amazon or e-Bay.

A number of scientific contributions focus on tagging as a type of user and community driven creation of meta-data (Heymann & Garcia-Molina, 2007; Hsieh, Lai, & Chou, 2006), or used tags to improve the accessibility of contents (Ishikawa, Klaisubun, & Honma, 2007; Michlmayr & Cayzer, 2007). Because free form tags provide an easy and flexible way for organising content and information, the number of commercial Web2.0 services supports tagging. Rivadeneira, Gruen, Muller, & Millen (2007) analysed different visualisations of tagging data with regard to the effectiveness of tag clouds on concept recall and visual recognition of information patterns.

A recent study (De Smet, Van Keer, & Valcke, 2008) analysed tagging with a pre-defined vocabulary with regard to the effect on accuracy and self-efficacy. The study analysed if peer tutors can appropriately tag their tutoring activities given the predefined vocabulary and if the tagging supports the tutors' self-efficacy beliefs. This research focused entirely on the effect of tagging for self-monitoring and self-regulation using a limited set of five tags. The authors found that tagging influences self-efficacy beliefs and self-regulation processes. Reflection *on* tagging was not considered by the study of De Smet, Van Keer, & Valcke (2008).

Other researchers (e.g., De Jong & Van der Hulst, 2002; El-Bishouty, Ogata, & Yano, 2006; Nussbaumer, Steiner, & Albert, 2008; Ogata & Yano, 1998) proposed and analysed visualisations of conceptual structures for supporting self-regulated learning. Like De Smet, Van Keer, & Valcke (2008), these studies focussed on predefined and pre-structured knowledge domains. Therefore, the design of these visualisations is linked to external learning objectives, which constrain the supported reflective processes. These studies addressed tagging or visualisation of concept structures in a formal learning environment. In these settings the learners could not extend the tagging vocabulary or the conceptual structures. In contrast to formal education, self-directed learning is defined by a high degree of learner control in weakly structured knowledge domains (Livingstone, 2001). This idea of learner control has already been implemented by many Web2.0 services that enable their users to create personal concept structures through tagging rather than replicating predefined ones (Smith, 2008) and has inspired the development of personal learning environments (Wilson, Liber, Johnson, Beauvoir, Sharples, & Milligan, 2006).

The concept structures in such environments can range from a few tags to a couple of hundreds and vary for each user. As a consequence of this freedom of the learners it is necessary that visualisations are designed independently from conceptual structures or knowledge domains. Related approaches (Erickson & Kellogg, 2003; Kreijns, 2004) visualise learner actions that were monitored by the supporting system – the "interaction footprints" (Wexelblat & Maes, 1999). These approaches are rooted in open-ended collaborative computer supported learning. This chapter analyses the phenomenon of tagging from the perspective of the individual learner. It combines and extends the prior research on visualisations of learner activity based on knowledge domain independent information (Chapter 5) as well as the research on using tags for identifying learner interests in open ended environments (Chapter 6).

Reflection

Self-directed or incidental learning, like it happens at workplaces or in online communities, depends on a person's ability to reflect on her or his actions. Therefore, reflection is a factor for this kind of learning (Schön, 1983, 1987; Ertmer & Newby, 1996). Schön (1983, 1987) distinguishes two variations of reflection that are relevant to learning: reflection on action and reflection in action. The main difference of the two kinds of reflections is the time when the reflection takes place in relation to the action. *Reflection on action* refers to those activities in which the learner reflects on past actions. This implies that the action that is focused by the reflection has already been completed and cannot be changed by taking insights resulting from the reflection into account. In opposite, *reflection in action* refers to those cognitive processes that are involved in the application of knowledge and experiences for assessing and controlling an ongoing task. In this case, reflection is directly related to and intertwined with the action in progress.

Ertmer & Newby (1996) define reflection as an activity that links *meta-cognitive knowledge* and *meta-cognitive control* (self-regulation). The authors emphasise that "reflection is critical for transforming the knowledge gained *in* and *on* action into knowledge available *for* action" (Ertmer & Newby, 1996, p. 18, emphasis in the original). The related processes can be clustered into three stages: *planning*, *monitoring*, and *evaluating*. "Reflection uses previous knowledge to gain new knowledge. At each stage in the self-regulation process, expert learners utilize the meta-cognitive knowledge they have gained from previous learning experiences to identify what the current task requires in terms of cognitive, motivational, and environmental strategies and to determine if their personal resources are adequate to effectively accomplish the task." (Ertmer & Newby, 1996, p. 18)

TENCompetence reflection use case

The TENCompetence project defined six core use cases for personal learning environments that support lifelong competence development. One of these use cases is called "reflect on competences" (Arjona, Lemmers, Glahn, & Sacristán, 2007). This use case describes the requirements for technical support of learners who reflect on their competences. The support is modelled as an interaction between a learner and a supporting system. This use case has six parts connected to reflecting on competence maps (Figure 7.1). A competence map contains information about the competences, proficiency levels (possible levels of a competence), and relations between competences that are required for a function or a job. From the learner's perspective, competence maps can be considered as visualisations of the underlying structure of competences, their relations among each other, and the possible proficiency levels.

In the first part of the use case the learner provides an estimation of the personal competence levels. This means that a learner enters the own perception of the levels of the selected competences. Alternatively, the learner can provide evidences about activities that are related to the competences in question. Based on the available information about a learner's activities and estimations the supporting system computes the levels and relations for all competences within a learning network, including those competences that are not achieved by the learner. The learner can then select a competence map of all competences or set a focus on particular competences to reflect upon. The competence map then shows either all competences and their relations or only those competences that are in direct relation with a selected focus. The learner can reflect on the provided competence map. In order to support the reflection process, the learner gets access to the results of previous reflections on the selected competence map. In that way a learner has access to previous reflection activities. The learner can also choose to provide a new reflection report to the supporting system. The new reflection report is available the next time the learner reflects on the competence map.

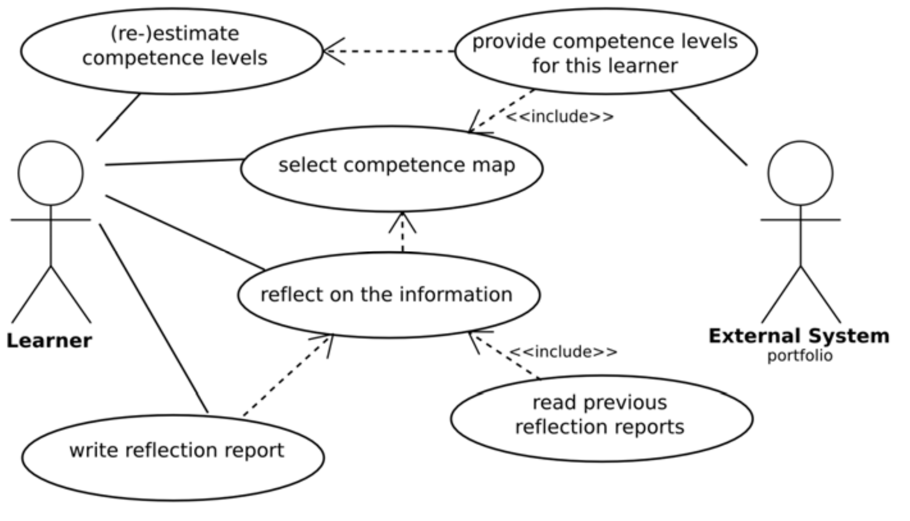

Figure 7.1: Reflect on competences use case in UML2 notation

Tags have no direct relation to competences and tag clouds are not visualisations of competences, but tag clouds are visualisations of concepts and relations between concepts. Such visualisations are maps of a learner's associations of concepts with objects and resources. Tag clouds are similar to competence maps in the way that they both provide evidences of a learner's activities. In tag clouds as well as in competence maps the information that is present for a user is aggregated from external information. The main differences between tag clouds and competence maps are the levels complexity of the underlying information. While tag clouds are based on free form “keywords” that are easily generated by a learner, competence maps are based on complex competence descriptions that are often the result of a professional standardisation process (Cheetham & Chivers, 2005). This reduced complexity of tag clouds over competence maps lowers the threshold for applications to integrate them.

ReScope

The present study used the ReScope system. ReScope is a tag cloud visualisation of a learner's tags in the social bookmarking service delicious.com. This service offers its users a tag cloud for the tags that are used by the user. This tag cloud encodes the global use of a tag in font size; i.e., the bigger a tag is displayed in the tag cloud the more often it has been used by the user. ReScope enhances the officially provided tag cloud by highlighting the tags that were used with the last 20 bookmarks of a user in different colours (Figure 7.2). The more a tag has been recently used, the stronger and brighter the colour of the tag will be. The ReScope tag cloud visualises the following types of information.

- The user's tags
- The overall usage of the tags
- The recent use of the tags.

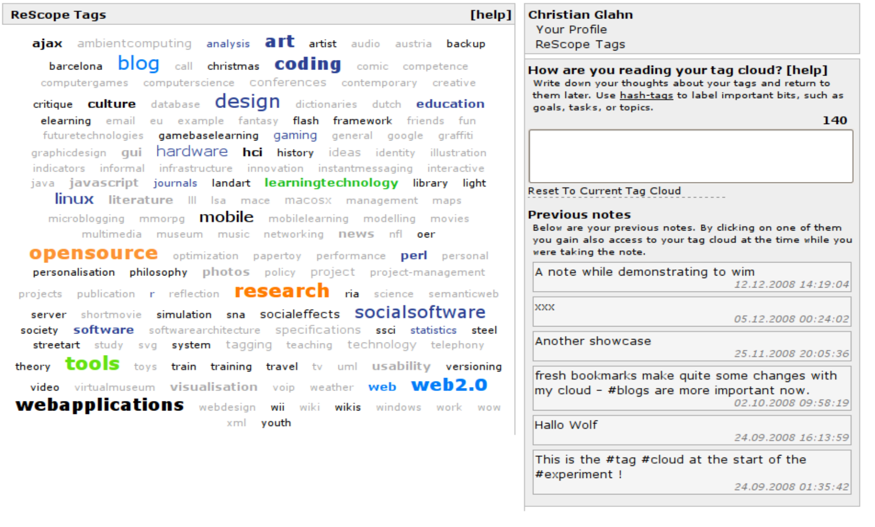

Figure 7.2: User interface of ReScope

The design of ReScope is based on the contextual dimensions *concept* and *process* of the contextualisation dimensions of situated learning. The tags and their overall usage indicate the relevance of a tag to the personal conceptual context of a learner. The colour codes of the most recently used tags indicate a tag's relevance in the context of the recent learning processes.

The integration of the most recently used tags makes ReScope more dynamic than the original tag cloud at delicious.com. By adding new bookmarks to delicious.com, ReScope immediately reflects the used tags in the visualisation. That way a user gets an impression on how the focus of the topics changes while bookmarking online resources with delicious.com. This highlights different types of information about the “learning” activities on the Internet (Stefaner, 2007). Although this information is entirely based on what was generated by the users it can serve as an anchor for reflecting about the personal tagging habits and the related knowledge structures.

ReScope tag cloud displays the tags alphabetically ordered. The overall use of the tags is encoded in the font-size of the tags and the recent use of the tags is encoded in colours. The more often a tag is used for categorizing bookmarks, the bigger are the letters of the tag. The more often a tag is assigned to the recent bookmarks, the brighter is the colour of the tag. Each encoding of information in the tag cloud allows the users of ReScope to analyse how they use tags in reading the web. By encoding the global and the recent usage of tags in a single tag cloud it is possible for the users to relate their general interests with their current web-readings.

Following the considerations of Stefaner (2007), ReScope can infer and highlight different types of information. This information is entirely based on the meta-data that is generated by the users themselves. For example, it is possible to identify emerging topics through ReScope. These topics have bright colours and smaller font sizes. Another type of information results from the way how the meta-data is presented to the users: through the multiple encoding of global and current tag usage, users may see relations between the concepts that are currently relevant while reading on the web. If more tags have brighter colours they seem to have some relation to each other, regardless of their global relevance. These relations might not exist at the level of tagged information, but may also result from a user's mental concepts. By highlighting these relations in the tag cloud a user has the opportunity to reflect on this information, explicitly.

Architecture and implementation

The underlying architecture contains a global tag aggregator, a recent tag aggregator, and a tag cloud visualisation that integrates both tagging information into a single view.

Both aggregators collect and combine the tagging information of a user from the user's information feeds. The global tag aggregator fetches all tags a user has used with the aggregated services. The recent tag aggregator fetches only those tags that are related to the most recent contributions of a user at a service. Each aggregation results in a tag table, in which each row contains a tag name and the frequency of its use. The results of both aggregators serve as input for the tag cloud visualisation. First, the tag cloud visualisation component renders the global tag cloud from the data provided by the global tag aggregator, and then applies the data provided by the recent tag aggregator. The information flow is illustrated by Figure 7.3.

The ReScope implementation of this architecture uses only tagging information of a user's public delicious.com bookmarks. By limiting the tagging information to a single service, it is possible to utilize the aggregation facilities that are provided by the service, which is in this case the delicious.com JSON feed API (delicious.com, n.d.). The API provides a direct interface to all the tags of a user, which can be interpreted as a replacement for the global tag aggregator. The recent tag aggregation is based on the most recent bookmarks of the user. Each bookmark has a number of tags associated which are embedded in the user's bookmark feed. From the perspective of ReScope, recency is relative to the 20 most recent bookmarks. This means that the time frame that is covered by the "recent tags" can vary over time, depending on the bookmarking activity of the user. In other words, when the user bookmarks many resources in a short time, the notion of recency will cover a shorter time span than in periods when the user occasionally bookmarks a resource. This implementation implies that the visualisation will change with every new bookmark.

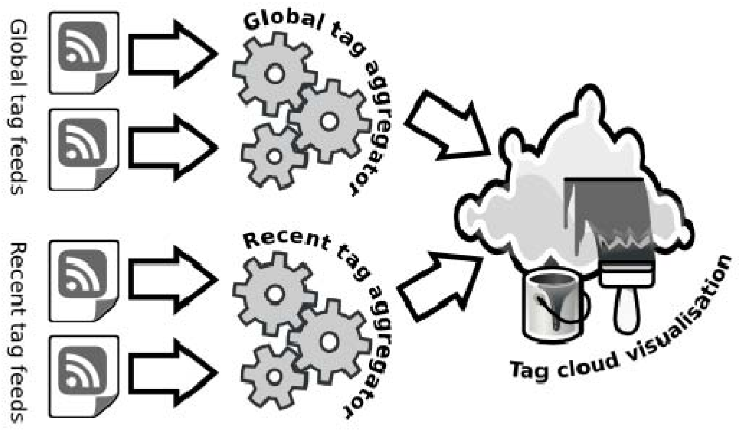

Figure 7.3: Interrelation of the ReScope components

The tag cloud visualisation is implemented as a JavaScript module, which is executed in the user's web browser. The formatting of the tag cloud is defined in a CSS file, in which each encoding is associated to a CSS class. Figure 7.4 shows the logical structure of the tag cloud. As the entire widget is implemented as a JavaScript module, it can be immediately embedded into existing web pages. All dynamic data is gathered from the remote services of delicious, and requires therefore no additional server-side components. By using the del.icio.us JSON interface, it is possible to make use of cross-site RPC calls, which cannot be achieved by using the XML based APIs in current web-browsers.

For very large numbers of tags, the tag cloud may exceed the available space on the screen. As a result, some tags might be off the screen and are easily ignored. Therefore, ReScope compresses large tag clouds in order to be fitted to the screen. For this purpose, ReScope analyses the number of tags and the number of times a tag has been used. If a tag cloud exceeds a given threshold of tags, the global tag list is ordered by the number of usages. In order to compress the tag cloud the usage of tag at the position of the threshold is checked. If more than ten tags with the same usage found below the threshold position, then the next bigger usage is used. In the latter case it is tested if the first tag of the tag list was used at least the number of times of the calculated use. This second test is needed to avoid that very scattered tag clouds are completely hidden. If both tests are positive, only the tags above the calculated usage threshold will be displayed to the user. In addition to the most popular tags of the user, ReScope injects all tags that were detected with the most recent bookmarks. Although this tag cloud "compression" is not optimal, it assures in most cases that the tag cloud will not exceed the available space on the screen.

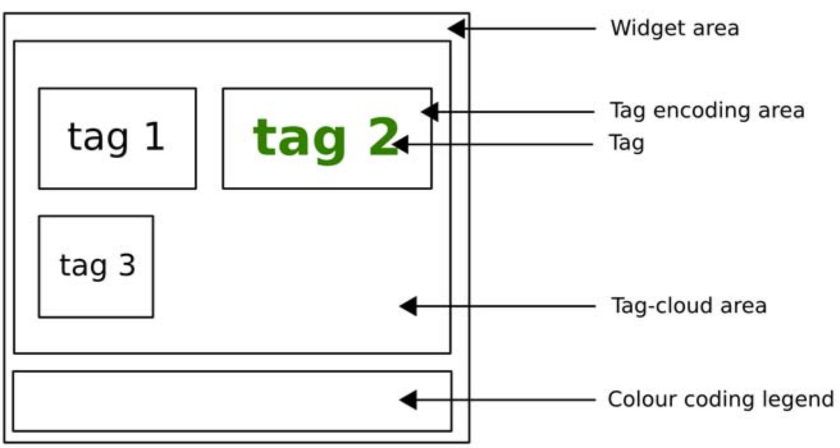

Figure 7.4: Logical structure of the ReScope tag cloud

Context dimensions

In Chapter 2 a context framework has been developed on the grounds of Lave and Wenger's work on situated learning (Lave & Wenger, 1991; Lave, 1993; Wenger, 1998; Wenger, White, John, & Rowe, 2005). From the perspective of this framework context is constructed through social practice. The context of a learner can be defined along the six dimensions *concept*, *event*, *participation*, peers, *process*, and *world*. The dimensions *concept* and *process* were considered for the design of ReScope.

Each tag in a tag cloud can be seen as a concept representation of a learner. Therefore, the delicious.com's global tag list provides the conceptual range of the learner's bookmarks. Each tag in the list also comes with the count of bookmarks, to which the tag is assigned. In the previous chapter is has been argued, that this information allows to infer the explicit interests of a learner. With regard to the concept dimension, the global tag count can be interpreted as the intensity of the relation between the learner and a concept, or in other words, the level of interest a learner has in a concept. By coding the tag count as the font size of a tag, this relation becomes visible and explorable.

In addition to concepts for supporting reflection ReScope embeds the process dimension in the tag cloud by aligning the colour coding of the tags to a relative time scale. In Chapter 5 an absolute time scale has been used for visualising data in the activity indicator. Compared to an absolute time scale that measures in minutes, hours, or days, the relative time scale of ReScope is related to the sequence of a learner's actions. An indicator that is based on a relative time scale adapts automatically to the pace of the learners actions. The range of time depends on the occurrence of events or actions, independently from their absolute timing. Therefore, relative time scales reflect the rhythm of the differences in measurement and experience of time: a relative time scale defines an interval in relation to events rather than to some external measures.

ReScope and the TENCompetence reflection use case

With the limitation that ReScope visualises only the tags that were used by a learner, the system can be considered as an implementation of the TENCompetence "reflect on competences" use case. In terms of the parts of the underlying use case delicious.com serves as a portfolio system that provides competence related information. This satisfies the "provide competence levels for this actor" part with the restriction that delicious.com provides only information about a learner's tags. In order to take full advantage of ReScope, users have to register with the system. While registering the users provide their delicious.com user name, so ReScope is able to fetch the tagging information from delicious.com. This requires a valid delicious.com account for using ReScope. Further, ReScope provides only a tag cloud of the personal tags used with the provided user name, which satisfies the "select competence map" part of the use case.

Additionally to the tag cloud, ReScope offers a note function. This note function allows learners to write short comments about their thoughts while viewing the tag cloud (Figure 7.2). As soon as the users of ReScope submit a note, a snap shot of the current tag cloud is stored with the note. This function implements the "write reflection report" part of the TENCompetence use case. The old notes are displayed in a reverse chronological list to the users below the note keeping system. The user can see older notes immediately. When a user clicks at an older note, the attached tag cloud is loaded so the user can see the same tag cloud that was displayed while writing the note. This function implements the "read previous reflection reports" part of the TENCompetence use case.

Research objectives and questions

For the personal learning process, the most critical part of the use case is "reflect on the information". This part refers to cognitive and meta-cognitive activity of the learner. In order to proof that a system fully satisfies the demands of the use case, it has to be confirmed that this activity is performed by the learners. This cannot be answered for tag clouds that visualise the results of tagging for a user. Therefore, this study has two main objectives: (1) identify if and how tag clouds can stimulate meta-cognition of learners regarding their self-directed and incidental learning on the Web2.0; and (2) identify design factors for the underlying use case for reflection support. Within this scope this study addresses the following three questions.

- Is ReScope a complete implementation of the TENCompetence reflection use case?
- Does the ReScope tag cloud stimulate meta-cognitive activity?
- Does the reflection on the tag cloud confirm contextual factors suggested by the contextual framework for situated learning?

This last question is necessary to understand the contextual use of tag clouds. According to the context framework that has been introduced above, it is expected that the notes can be linked to the context factors *rhythm*, *value*, and *connection*. Rhythm refers to all types of structuring a process. Value covers anything that is related to the added value of concepts and conceptual structures for the learner. The factor connection refers to the structure of the concepts as well as the relation of concepts to resources. The factors "integration" and "community building" are not expected to occur, because the factors are directly related to connections between peers, which are not facilitated by the system.

Method

In order to answer the last question, the participants were invited through advertisings on several mailing lists, web-logs, and web-sites of related research projects. Furthermore, ReScope has been announced at two European conferences in the domain of computer assisted learning. The participation was entirely voluntarily.

Interested users could visit a demo of ReScope that allows seeing the tag cloud visualisation for any known user account. For this demonstrator an example user name is provided as default. This allows visitors to get an impression of the tool without the need of having an account with delicious.com or to register with ReScope. In the demo version only the most recent tag cloud without the note taking function was available. Apart from having an account with delicious.com and ReScope, no further restrictions were made regarding the use of the system. After the registration all users were asked to fill a questionnaire about their use of the delicious.com service. This questionnaire included also basic demographic measures such as gender and age. This questionnaire was only available to the participants at their first visit.

The interface of the ReScope system included information texts that asked the participants to write down their thoughts about their reception of the tag cloud in the notes field and to label important aspects with a hash ('#'). This technique is called "hash tagging" and has been used with other social software systems that lacked of direct tagging. In addition to the short information on the main screen ReScope provides a set of longer help pages that explained the different parts of the system to the participants. These help pages contained a description of ReScope's note taking system as well as the meaning of the colour codes.

For monitoring the interactions of the participants with ReScope, the system is extended with user interaction sensors. These sensors track the visits to the different parts of the system, the note taking, and the accesses of the older notes that loaded a snap shot of the personal tag cloud.

Nine weeks after the initial announcement of the system a snap shot of the system's usage has been taken and analysed. This snap shot includes the tracking data from the user interaction sensors, the answered questionnaires, and the notes taken by the users. Notes that contained only "noisy" statements like "hello" or "xxx" were removed before starting the analysis. The remaining notes were labelled with the three types of meta-cognitive control of Ertmer & Newby (1996): evaluate, plan, and monitor. Additionally to this model based labelling, all notes were clustered based on the contained information using content based labelling. The tracking data was analysed regarding the frequency of using the system in terms of returning visits, and regarding the use of the different features of ReScope. The results of the questionnaire were only used for the demographics of the participants of this study.

Results

Over the period of nine weeks, 76 users have registered with ReScope. By checking the national domains of the registered e-mail addresses, participants from 13 countries were recognised. Most participants came from the UK, Germany, and the Netherlands (n=34), or registered via an email of a free-mail provider (n=26). 56 participants answered the initial questionnaire. 42 of the respondents were male and 14 were female. In average, the respondents were 36 years old; the youngest participant was 22 and the oldest was 58 years old. The majority looked at the personal tag cloud at delicious.com (91%), although 73.5% of the respondents stated that they look at their tag cloud on delicious.com only sometimes or rarely. Eleven participants returned to ReScope at least once after the initial visit. Nine of these participants left 43 notes about their tag cloud. Only one participant actually accessed an old note and loaded the associated tag cloud. After cleaning the noise from the notes, 35 notes remained that described reflective activity of their authors.

The first notes of five users reflected their surprise over the structure of their personal tag cloud and expressed the need to adjust the tags. An example for these notes is given by User A.

"I have too many occurrences of singleton tags #clean-up".

The note of User A also contains a hash tag. The hash tag feature has been used by six participants in 14 notes. As expected, the participants embedded the hash tags directly into the statement of the note. Some notes had several hash tags assigned. The following two examples illustrate the use of hash tags. In the first note, User F stated.

"need to cut out #duplicate_tags".

A more complex example of hash tags is given by the following statement of User D.

"Writing on my #blog (++space) I realised I hadn't used #tag podcast very consistently. #consistency important, so I #edited the post."

Given the small number of notes using hash tags and the lack of social exchange between the users, it was not expected that the participants shared hash tags among each other. Nevertheless, the provided hash tags were helpful to label the notes during the analysis.

In a first step, all messages were labelled according the three types of reflection for meta-cognitive control: evaluate, plan, and monitor (Ertmer & Newby, 1996). All notes were categorised regarding the three types of reflection. One note was labelled with evaluation and planning because the note stated first the result of a self-evaluation and then defined an objective for future tagging. 17 notes are labelled as evaluative reflection, six notes as planning, and 13 notes as monitoring.

The results from the model centric labelling suggest that all three types of reflections were identified with the notes (Table 7.1). The majority of the notes were labelled as evaluative reflection. This was partly expected from the context framework that emphasised the concept related dimension. However, in this case the focus on the semantic structure is more likely because the system was not used frequently over a longer period. Therefore, the results are influenced by initial notes, in which the participants refer to the need of cleaning up the semantic structure of their tags. These notes make 20% of all notes and 41% of the notes that were tagged as evaluative reflection.

In a second step, all messages were categorized regarding the type of the note. After this procedure a note could have many labels assigned. This step brought up three key categories: 23 notes were reflections about the semantic structure of the tag cloud, six notes were reflections on organising the tagging process or on aligning it with other tasks, and nine notes were reflections on system features. Additionally, two notes were labelled as reflections on social interaction and one note was labelled as a personal remark. Four notes were classified as follow-ups to prior notes. These follow-up notes were not extensions of a preceding note because of the length constraint for the notes, but marked steps in a process. Within the notes on the semantic structure, three sub-categories were identified. The participants reflected in seven notes on the need of cleaning up the tag structure, in eight notes about the consistency of how the tags were used, in two notes about emerging tags.

Within the three key categories of the second step the feature related reflections are interesting. First, no notes of the planning type were found in this category, which could be expected, because the participants could not change the system's behaviour. Second, the remaining notes appeared to be part of a self-assuring process, in which a participant relates personal impressions to the presented information. An example of this process was found in the notes of User D. A first note reports on a mismatch of the personal impression and the visualisation of the tags.

> *"Looking at this tag cloud I'm surprised how small the tag "web2.0" is rendered. I thought this was one of the tags I used a lot #reflection"*

In a follow up note six weeks later the participant states.

> *"Why does #rescope show "web2.0" in smaller font than "podcasts", I have 102 posts tagged "web2.0" and only 30 tagged "podcasts"?"*

The effect described by the participant is an optical effect that occurred with more frequently used tags. The font size of the global tag usage is not based on a linear scale: with higher usage counts the tags do not grow as fast as for smaller counts. With the counts mentioned in the note, the smaller "podcasts" *appears* optically bigger than the tag "web2.0", because even with a smaller font the tag with more letters takes more space on the screen. However, given the notes the participant *expected* the "web2.0" tag to be visually bigger than the other tag. The notes show that the participant was first surprised by the visualisation and then monitored the visualisation in order to confirm the own impression about the tagging practice.

Analysis of the findings

This study focused on the potential of tag clouds for supporting reflection on the personal tagging of self-directed learners. It combines and extends the prior research on visualisations of learner activity based on knowledge domain independent information (Chapter 4, Chapter 5) as well as the research on using tags for identifying learner interests in open ended environments (Chapter 6).

The use case on using competence maps for supporting reflection on learning experiences has been provided by the TENCompetence project. This use case is a concept study following a smart design approach. The use case for reflection support can only get partially validated by a technical implementation, because it includes the reasoning of the learner on the presented information as a non-functional requirement. Although the present ReScope system is based on different aggregations of tags rather than a competence map, the tag cloud can serve as prototype of a competence map visualisation. The results of the present study suggest that ReScope meets the non-functional requirements of the use case within the limitations of a keyword based tag cloud. This answers the first question of this study.

The second question was partly answered by the results of this study. The results indicate that already the rather simple visualisation of tags provided by the system stimulates reflection. This conforms to the concepts of meta-cognitive control (Schön, 1983, 1987, Ertmer & Newby, 1996). The notes of the content based labelling are equally distributed across all types of reflection (Table 7.1). This suggests that the tag cloud supports meta-cognitive processes in self-directed learning at the levels of evaluating (reflection *on* action), monitoring (reflection *in* action), and planning (reflection *for* action).

Table 7.1: Relation between content and model based labelling

	feature	*process related*	*semantic structure*	*consistency*	*clean-up*	*emerging topics*	*general reasoning*
evaluate	4	3	5	3	4	0	3
plan	2	2	3	3	2	0	0
monitor	1	2	6	3	1	2	0

De Smet, Van Keer, & Valcke (2008) argue that working with tags "offers tutors an efficient thinking tool that fostered an initial higher degree of active tutoring" (De Smet, Van Keer, & Valcke, 2008, p. 469). While the authors used a limited set of labels, self-directed learners may create much larger numbers of tags to organise their resources. Based on the present results it can be argued that tagging as a thinking tool can be enriched by the visualisation of the tagging information and that it supports self-directed learners. Moreover, the results of this study indicate that visualised tags are not only used for self-monitoring, but also for planning and evaluating actions.

Regarding the third question the results of the content labelling can be interpreted as instances of the context factors for situated learning. By mapping the identified labels on the context factors, it becomes possible to address the third research question. The design of the tag cloud focused on the context dimensions *process* and *concept*. Therefore, it is expected that the participants' notes are related to the context factors *rhythm*, *value*, and *connection* (Figure 2.2). Notes that were labelled only as *semantic structure* but not to any of the sub-categories were mapped to the connection factor, because these notes reflect the relations between the tags and the relations between tags and resources. Notes of the categories *process related* and *emerging topics* were mapped to the rhythm factor. Finally, the notes of the categories *clean-up* and *consistency* were mapped to the value factor, because these notes refer to the value of the tags for the personal information management.

By re-evaluating the content labelling data using this mapping, the relevance of each factor for the participants' reflection can be estimated. Taking the impact of the initial statements into account, the given distribution suggests that the reflections related to the three factors were equally stimulated by the tag cloud (Table 7.2). This finding supports the initial expectations regarding the influence of contextual factors on the reflection of the participants.

Table 7.2: Relation between context factors and reflection types

	rhythm	*value*	*connection*
evaluate	3	7	5
plan	2	5	3
monitor	4	3	6
Total	**9**	**15**	**14**

Limitations of the interaction design

The findings of this study are constrained by the gap in the numbers of registered participants and those who used the system. An initial analysis of the user information in the system suggests two problem fields. Firstly, for participants with a few resources and a small number of tags, the tag cloud provides little valuable information. For these participants there was not much to see. Secondly, for more advanced delicious.com users a slightly different problem could be identified: the direct benefits are not immediately visible to the learner. These participants see a coloured tag cloud and an empty notes block, but it appears that the benefit of using the system was not directly visible to them.

The prior research has indicated that *playing a system* may help learners engaging with the system and learning its functions (Chapter 5). The setup of ReScope that displayed only the personal tag cloud and an empty note list, gives learners not much room for playing the system, because the system design is based entirely on the tagging data provided by delicious.com and on the notes taken by the participants. The participants were asked to take notes, so they *might* see changes in their tag cloud at their next visit. In addition to taking a note, visible changes also require that the participants tag new resources on delicious.com. This task may take some time and effort before something can be recognised by the learners, whereas *playing a system* refers to direct and immersive interactions with a system. The informative and instructive texts provided in the user interface and by the help system of ReScope were not a sufficient replacement for immersive interactions.

One way of allowing playful interaction with the personal tagging information would be *simulated* notes on prior tag clouds. This can be achieved by taking the tags of older resources into account for the visualisation. For example, previous views of the tag cloud could be simulated by visualising older intervals of tag usage. Through such simulated snap shots the system could offer pre-filled notes to the participants already at their first visit. This would enable immediate interactions with the system and help users to learn about how they can benefit from using the system. In order to offer simulated notes, the participants need to have a tagging history at delicious.com. Such a history is not available for new or occasional users of delicious.com, who have only a few resources bookmarked at the service. These users are therefore disadvantaged for exploring the benefits of the system.

Limitations of the study

The present study analysed if a visualisation of free form tagging data can support meta-cognitive control of self-directed learners. The study focused only at the participants' *explicit reflections* that were present in their notes. This has a number of shortcomings that have to be addressed by further research.

The present research is limited at ways how self-directed learners reflect on their personal tagging actions. This neglects two critical aspects of self-directed learning processes in Web2.0 environments: social interaction and implicit learning actions. Although ReScope uses data of a social software service, the system uses only the personal information of a participant. Further research has to analyse if the findings of this study can be confirmed with a system that allows social interaction. A second shortcoming is that tagging is an explicit activity. Therefore, the tag cloud will display only information that has been previously used by the learner. The tags can therefore be considered as the result of a learner's earlier reflection.

The interpretation of the results indicates that visualisation of tagging information can be beneficial for meta-cognitive control. However, the data refers only to the notes provided by the participants and did not analyse how the visualisation influences the learners' beliefs, their concept awareness, or their self-regulation in self-directed learning.

Conclusions

Reflection has been described as the learner's assessment and validation of experiences in problem solving and social interaction against conceptual structures and strategies. This process is part of developing consciousness about the relations between actions, beliefs, and concepts. Therefore, reflection is a relevant meta-cognitive process related to learning. This chapter analysed if a tag cloud visualisation of a learner's free form tags can stimulate such meta-cognitive processes. The study has two outcomes.

A personal tag cloud can stimulate reflection on the tagging activity of a learner. Using the highlighted tagging information supports the learners to evaluate and monitor the semantic structure of the resources that are found on the web. Additional tools such as note keeping or a track record of a learner's tagging history may support the learners analysing their actions and concepts, but these tools are not required for reflection.

The concepts of situated learning can be applied for developing technological support for self-directed learners. By focussing at the context factors that were identified for situated and collaborative learning it is possible to provide targeted solutions for supporting meta-cognitive control.

The findings of this qualitative study indicate that targeted solutions for supporting meta-cognition are not dependent on pre-structured domain knowledge or educational designs. This opens opportunities for developing new forms of supporting self-directed and incidental learning in learner controlled environments.

Chapter 8
General Discussion[1]

Contextualisation is a new field in technology enhanced learning. While contextualisation is often considered in mobile and ubiquitous learning scenarios, mobile and ubiquitous learning commonly chooses a technology centred view on supporting learning processes. In this research area location is most commonly chosen as the central dimension for contextualisation. The choice for location as the central contextualisation dimension comes certainly not by accident: location based services have attracted a lot of commercial attention; and without doubt, these services hold great potential for applications in the educational field. The previous eight chapters, however, provided a different perspective on contextualisation. Starting from the background of self-directed and incidental learning of adults in web-based environments, the benefits of social software and the Web2.0 were of greater interest for this research than mobile and ambient computing devices. Nevertheless, this thesis shares some theoretical background with the research in mobile and ubiquitous learning: the theory of situated learning (Lave & Wenger, 1991).

While prior research in the domain of mobile and ubiquitous learning emphasises *situated learning* in terms of *located learning*, Chapter 2 outlined that the theory of Lave and Wenger (Lave & Wenger, 1991; Lave, 1993; Wenger, 1998; Wenger, White, John, & Rowe, 2005) is of greater complexity. By analyzing the work related to this theory, six contextual dimensions were identified. These dimensions were then mapped onto context factors that were reported by prior research (Wenger, 1998). This mapping spawns a conceptual framework for modelling and analysing context centred social interactions. The framework emphasises the relation of social practice and context for modelling and analysing technological support for contextualised learning – not only by mobile and ambient technologies, but also by web-based services.

The objective of this research was to develop approaches for supporting self-directed and incidental learning processes. This kind of learning is often related to weakly structured and emerging knowledge domains, in which the learning processes are not

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[1] This chapter is partly based on:
Glahn, C., Specht, M., & Koper, R. (2009b). Perspective and contrast, design principles for supporting self-directed and incidental learning. *Accepted for the 9th International Conference on Knowledge Management and Knowledge Technologies (I-*KNOW *2009)*, September, 2-4, 2009, Graz, Austria.

pre-structured and often unconscious to the learners. Supporting learning under these conditions faces specific challenges that are related to uncertainty at the levels of learning objectives, of a learner's competence levels, and the knowledge domain. Therefore, this research focused on solutions that are independent of these levels.

One way to support learners under these conditions is visualising information that allows learners to create meaningful relations of their learning endeavours and to the context of their learning activities. This thesis discusses the use of *indicators* of interaction footprints for supporting learners to analyse and to manage their learning processes. Indicators are simplified information visualisations that are valuable for the learner.

According to theoretical models of self-regulation and motivation (Butler & Winne, 1995; Garries, Ahlers, & Driskel, 2002) the value of the information refers to a learner's meta-cognitive processes that analyse the effects of an action in relation to intentions, knowledge, and strategies (Butler & Winne, 1995; Ertmer & Newby, 1996). Interaction footprints are traces of a user's interactions with a system. As such, interaction footprints are valuable resources for responding to learners. Moreover, interaction footprints are commonly used in context aware and adaptive systems for process control, adaptation, and personalisation.

Based on the models on self-regulation and motivation as well as the research in the context of situated learning, it was suggested that the value of the information presented by an indicator for self-regulation depends on the learners' context. This means that the information provided by indicators should respond meaningfully with respect to this context. This drew the attention to context aware systems (Dey, 2001; Zimmermann, Specht, & Lorenz, 2005), of which key concepts were adopted for designing a system for contextualising activity indicators. Based on a model based architecture (Zimmermann, Specht, & Lorenz, 2005), a review of existing visualisation approaches has been conducted (Chapter 3) and a strategy has been proposed for contextualising indicators in a social software environment (Chapter 4).

Part 2 of this thesis focussed at two areas for supporting self-directed and incidental learning: *social interaction* and *personal information management*. Within these areas two aspects of support were the major interest of this research: *engagement* and *reflection*. The structure outlined by these chapters can be linked to *learning-in-practice* as it has been defined by Lave (1993): *learning-in-practice* is the interplay of the two aspects *understanding* and *participation in ongoing activity* (Lave, 1993, p. 9).

Each chapter in the second part of this thesis addresses different aspects of context for the learning process. Chapter 5 focused on context dependency of visualisations of interaction footprints and analysed a *control strategy* for supporting engagement in social interaction. Chapter 6 studied different *sensor information* with regard to their context dependency in social interaction. The chapter analysed if the information obtained from active tagging is different from the information that is identified by the tags that are assigned to the resources a learner used. Chapter 7 concerns the use of a tag cloud as an indicator for personal reflection support. The design of such an indicator is discussed at the level of *aggregators* and information arrangement for *visualisation* for supporting reflection by integrating the two context dimensions *process* and *concept*. This design is then empirically analysed if the contextual design for reflection support influences for meta-cognitive processes accordingly to the proposed context framework for situated learning.

Key findings

Chapter 3 provided a review of the prior research on indicators. Based on the findings of this review the chapter concluded by raising three main questions for further research. This section discusses these questions based on the findings of the design studies in Part II.

What contextual information is relevant to support the learning process and does this information change throughout the individual learning process?

From the re-assessment of the earlier research of Lave and Wenger, context dimensions and context factors were identified and combined into a context framework in Chapter 2. According to the work of Lave and Wenger (Lave & Wenger, 1991; Lave, 1993; Wenger, 1998) learning is situated in context. Within this scope context is socially constructed. The results of the design studies that are discussed in Chapter 5 and Chapter 7 suggest that the selected dimensions and factors of the context framework were helpful in the design process of the indicators and for foreseeing the effects of the design. Including the findings of Chapter 6, the results suggest that the data from underlying sensors themselves are not providing contextual information for a learner, but that it is a result of aggregation and the visualisation of the data. Such aggregation can be designed according to the dimensions and factors of the context framework that has been defined in Chapter 2. Based on these factors and dimensions sensor sources can be selected and combined for data aggregations that support learning. Therefore, it is needed to distinguish clearly between activity data and aggregated information while designing learning support tools.

The findings of the qualitative studies in this thesis suggest two *design principles* for providing contextualised learning support:

- *Perspective*
- *Contrast*

Perspective describes the way how the sensor information is aggregated by the system. By adding perspective to the aggregation learners can create meaningful relations between their actions and the responses of a system.

Contrast describes the way how different aggregations of different perspectives are visualised. Through contrast the learners can assess the value of their actions in comparison to a reference dimension. The reference dimensions discussed in this thesis were *community* (Chapter 5) and *global tag usage* (Chapter 7).

How can a system collect data and aggregate contextual information in a way that it can provide meaningful information at the different stages of a learning process?

The general architecture for context aware systems (Zimmermann, Specht, & Lorenz, 2005) has been successfully implemented for providing indicators for supporting learning by the systems that were used in the studies. As mentioned above, the selection of the underlying sensors depends on what aggregators are used. The findings (Chapter 5, Chapter 7) indicate that the design of aggregators and of visualisations for indicators can be grounded on the dimensions and factors of the context framework of situated learning (Chapter 2). The results of Chapter 5 indicate that the same information visualisation can have very different effects for learners at different levels of participation. These findings partially support the initially proposed contextualisation strategy (Chapter 4).

The principle for designing the aggregation of sensor information for learning support is *perspective*. This means that the data of each sensor can be aggregated from different perspectives. In Chapter 5 and Chapter 7 *time* perspective on sensor data was chosen. This means, only parts of the available information is used for the aggregation. Chapter 5 compared visualisation of data from an *effort* perspective with the perspective of this data as action *events*. The performance indicator displayed the *personal* information with the data of the same sensors from a *community* perspective. These perspectives were aggregated of an *absolute time* interval of seven days. The tag cloud indicator in Chapter 7 contrasts tagging information over a *relative time* interval with information over the *entire period*, in which a learner contributed to a service.

The study in Chapter 6 could not find differences in reading habits of tagged information in an online portal. This suggests that implicit learning activities can provide data on a learner's implicit interest. This implicit interest might be used to enrich the information on the learner's explicit interests. Because prior research (Claypool, Le, Wased, & Brown, 2001; Farzan & Brusilovsky, 2005) found that implicit interest expressions only provide weak evidence on a learner's interests or progress, it can be assumed that sensor aggregation should weight the different sensor information with respect to the context of a learner. After comparing the findings in Chapter 6 and Chapter 7 it appears that the weight of the sensors also depends on the perspective that has been chosen for the aggregation.

What is the effect of different aggregators, strategies and indicators on the learning process and how can they get effectively combined and applied for supporting the learning process?

Chapter 5 reported that the same underlying sensor information had very different effects on the participants of an online design study. Chapter 7 argued based on the example of a multi encoded tag cloud that embedding different aggregators on the same data supports the learners' reflection on their tagging activities. In both cases the indicators are stimulating the learners' meta-cognition at the levels of social awareness (Chapter 5), conceptual relations (Chapter 7), and process awareness (Chapter 5, Chapter 7). While the study of Chapter 5 reported that such stimulation depends on the indicator, the aggregated information, and the participation context of the learner; the results of Chapter 7 suggests that the stimulating effect can be designed on the foundation of the context framework that is proposed in Chapter 2.

Another aspect is an effect that can be called *playing the system*. Playing the system describes a learner's interaction in two ways: firstly, it describes the process of engaging activities that help a learner to learn about the facilities and features of a system; secondly, it describes a type of challenging engagement with a system during the normal use of a system. In Chapter 5 it is argued that the former way is relevant for learners to create a meaningful relation to a system and a group of peer users. Chapter 7 discusses that through the lack of this kind of challenging a system creates a barrier for potential learners for using a system. The findings of the design studies also suggest that some indicators can support this first type of playing a system (Chapter 5), but that this form of interaction is not an inherent feature of all indicators (Chapter 7).

Design principles

The objective of a design research project is to identify design principles that can support theory development and that can serve as anchors for further research. This thesis explored the design principles of information visualisation and contextualised adaptation for supporting self-directed and incidental learning. One of the challenges of design research projects is the generalisation of the findings. This section discusses the general design principles that were identified by this research.

This research started with a four layered architecture for context aware systems. Both systems of the design studies, team.sPace and ReScope, implement this architecture of sensors, aggregators, indicators, and controllers. Sensors refer to data that is directly related to the learners' actions. Every data that is collected at this level is an interaction footprint. Aggregators refer to semantically enriched information that is based on sensor data. An aggregator defines a rule set how the underlying sensor information has to be aggregated. Indicators describe the presentation mode of aggregated information. An indicator defines what information is highlighted or diffused in what way. Controllers refer to dynamic and adaptive processes. Each controller implements an adaptation strategy that arranges the interplay of aggregators and indicators.

This architecture also allows the abstraction of the information processing. The abstraction is helpful to distinguish between the types of data that is provided by systems and services or that is described in specifications. For example, the attention meta-data specification refers to one particular aggregator that integrates and represents a set of sensor data of a system. Although some sensor data is directly represented in specific fields, it does not provide ways to access all data that is collected by these sensors. Another example for an aggregator is the delicious.com feed API (delicious.com, n.d). This programming interface provides pre-aggregated sets of the data that is collected by the system. Although it is very likely that other aggregations of this data would be possible as well, there are no simple ways to implement alternative aggregators on delicious.com's sensor data that are beyond the predefined feeds. A similar distinction can be made for controllers. For example, IMS Learning Design (IMS LD) provides a specification for defining (specialised) control strategies. Although IMS LD level B also provides simple aggregation and data capturing functions, the scope of the specification is the orchestration of resources and actors with interfaces. In order to make design decisions for systems that support learning it is necessary to identify at what level the support is reflected. Examples for systems that are based on such reflection are team.sPace (Chapter 4, 5, and 6) and ReScope (Chapter 7).

Although the architecture for context aware systems can serve as a generalised framework for describing systems that can support self-directed and incidental learning, the findings of this research indicated that the architecture is not sufficient to make design decisions for such systems. The design principle for supporting self-directed and incidental learning is *contextual personalisation*. This design principle describes that learning can be technically supported by personalising the system to the needs of a learner. This type of supporting learning is personalised because it relies on the learner's activity rather than a predefined knowledge domain or learning design.

Contextual personalisation reflects that the needs of learners depend on the learners' context. The findings of the design studies suggest two subordinate principles for contextual personalisation: *perspective* and *contrast*. Together these principles reflect learning as a transformation process of a person in a context.

The objective of this type of learning support is to highlight different aspects of the learning process to the learner. The activity indicators that are described in Chapter 4 and 5 highlight the learner's activity and allow to see changes of the own activity over time. The ReScope tag cloud (Chapter 7) allows self-directed learners to experience conceptual changes in their web reading interests by visualising tags that are assigned to bookmarks. The highlighting of the selected aspects of the learner's activity relies on the principle of *contrast*. Through this principle it can be explained, why the action counter of team.sPace – which lacked of contrast – received such little attention in the design study (Chapter 5). The performance indicator in team.sPace (Chapter 4 and 5) and the ReScope tag cloud (Chapter 7) reflected this principle and were stimulating the learners' engagement and reflection more constantly.

The different perception of information that is presented in the indicators follows the principle of *perspective*. The perspective corresponds to learners' attitude towards an environment. A design might integrate a set of perspectives. For example, team.sPace can be connected to a *community* perspective and the indicators extend this perspective through *effort* as a perspective, and ReScope is related to a *personal* perspective that is coupled to a *time* perspective. For team.sPace the perspective principle helps to explain the different perceptions of the action counter and the performance indicator (Chapter 5). The action indicator displayed only a learner's own actions it did not meet the needs of the collaborative perspective for all users. Therefore, it was then ignored by contributing and non-contributing participants. The underlying rule set of the performance indicator emphasized the activities of the contributing participants within the collaborative context, which can be used to explain why the perception of this indicator was different for contributing and non-contributing participants. In other words, the performance indicator reflects a "contributing collaboration" perspective.

In order to become relevant for further research, the design principles are combined with the reference architecture for context aware systems that serves as a design framework. The findings of Chapter 6 suggest that the single actions of a learner are independent from both design principles perspective and contrast at the level of sensors.

The perspective principle can be reflected at the level of aggregators and controllers. In the first design study the concept of perspective was only implicitly reflected in the design, but the findings suggest that the perspective principle correspondents to aggregators and to their arrangement in an adaptation strategy. This insight has been applied in the design of the ReScope tag cloud of the second design study.

The contrast principle can be associated to indicators and the arrangement of aggregators in an adaptation strategy. This suggests two types of contrast. The first type can be described as visual contrast. This type reflects the presentation mode of the information at the level of an indicator and allows a learner to compare and relate different aspects of contextual information. The second type can be described as information contrast. This contrast type is related to the arrangement of aggregators and depends on the type of information that is provided by the contrasting aggregators.

While contrast at the level of indicators mainly addresses the visualisation of information in terms of usability, is contrast at the level of controllers focused on the arrangement of potentially meaningful information. At this level the aspects of perspective and contrast are tightly coupled in the design decisions. In this thesis the designs for supporting self-directed learning processes were based on the contextual framework that was developed from the literature on situated learning (Chapter 2). This framework defines relations between contextual dimensions and context factors and has been used a guide for defining, selecting, and arranging aggregators for supporting self-directed learning processes.

Whereas the design principle of contextual personalisation with the subordinate principles of perspective and contrast aims directly at the design of supporting functions, the findings of this research indicated another design principle for systems that support self-directed or incidental learning. This principle can be titled as *playful interaction* and reflects the responses of the participants of the design studies of team.sPace (Chapter 5) regarding "playing the system"; and ReScope's lack of a similar feature (Chapter 7). This design principle is relevant for systems that focus on supporting self-directed and incidental learning, because the learners in these settings need the opportunity to explore the benefits of a system for their personal learning activities. The playful interaction has therefore the primary objective to lower the barrier for beginning to use a system. Therefore, this principle demands that learners need to be able to explore the functions of an online system from the very beginning in order to understand how they can benefit from using it. This means that the design of a system should consider that a learner needs direct responses while using the system the first time. Further in the process, this design principle guides the design decisions that help learners to externalise learning goals into achievable tasks.

Lessons learned for research and practice

The findings of this research provide only initial answers on the three key questions. However, the findings suggest despite all their limitations that the concepts of situated learning can be applied for developing technological support for self-directed learners. By focussing at the context factors that were identified for situated and collaborative learning it is possible to provide targeted solutions for supporting meta-cognitive control. This implies that situated learning can be technologically supported beyond providing and arranging tools for learners and communities. This has consequences for the development of personal learning environments (PLEs). PLEs are considered as tools for self-directed learning. So far, the focus lies on coordinating connections between the user and services for integrating experiences in a range of environments, including education, work, and leisure activity (Wilson, Liber, Johnson, Beauvoir, Sharples, & Milligan, 2006, pp. 176-177). With the help of indicators it becomes easier for the learners to recognise and reflect their learning experiences in these environments.

Indicators can provide valuable information that allows learners to create meaningful relations between their actions, their knowledge, and their environment. Both indicator related studies have indicated that the used indicators are beneficial for stimulating meta-cognition about the own learning activities and about the dynamics of the environment. This implies that indicators that use interaction footprints are not only system responses, but can be considered as a type of feedback (Mory, 2003). The results of this research suggest three underlying factors for this feedback type: first, the type of presentation; second, the available footprint data; and third, the social practices of the learner. By focussing at the factors and dimensions of the context framework that has been developed by this research it is possible to provide targeted solutions for different contexts and social practices.

Within the scope of this study only three of the six context dimensions of the framework were analysed. The findings suggest that information visualisation is relevant for self-directed learning, but it is constrained by the context and social practices of the learner. This raises questions in four directions that should be addressed by future research. Each of these future research directions should aim for more detailed answers on the three main research questions in relation to the design principles.

The first direction concerns the effects of activity indicators on the quality of learning in terms of self-efficacy, knowledge and concept elaboration, and task performance. The guiding questions of this direction address the relation of activity visualisation with the outcomes of the learning process.

The second direction covers the interplay of the dimensions and the related factors for contextualisation of learning experiences. This direction implies also the relation of dimensions that contextualised social practices with other theories of contextualisation.

The third direction concerns the transfer of the context framework to other areas of contextualised learning, such as mobile and ubiquitous learning. The research problem of this direction is related to the question, in what way the social practice related to the different technologies influence the learning processes.

Finally, it is needed to identify appropriate combinations of sensors, aggregators, and visualisations for the different factors and analyse the contextual conditions of these arrangements. This direction addresses the different kinds of learner support using visualisations of interaction footprints.

Final remarks

The findings of this thesis indicate that it is possible to develop and provide targeted solutions for supporting self-directed and incidental learning. By using interaction footprints these solutions can be independent from pre-structured domain knowledge or educational designs. This opens opportunities for developing new forms of supporting self-directed and incidental learning in learner controlled environments.

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Summary

This thesis analyses the role of context for supporting self-directed and self-organised learners on the web. The goal of the related project was to develop novel approaches to provide feedback on learning actions in knowledge domains and social environments that are not pre-structured for instruction. For this purpose simple visualizations of learner activity, so called indicators, were added to web-based information systems. The research question of this thesis is whether the perception of such indicators is context related.

The thesis reports on exploratory design research and consists of two parts. The first part covers the theoretical and conceptual research. The second part analyses effects of indicators that were observed in the design studies that were related to this thesis.

Part I has three chapters: "three pillars for research" (Chapter 2), "smart indicators to support the learning interaction cycle" (Chapter 3), and "smart indicators of learning interactions" (Chapter 4).

Chapter 2 discusses the theoretical background of this thesis. The chapter starts with situating the research in the larger context of lifelong competence development and learning in the professions. Within this scope the focus on self-directed and incidental learning is contrasted with other types of education and learning. Based on these foundations the chapter elaborates the three theoretical pillars for this research: situated learning, feedback, and information visualisation. These pillars contextualise the system design and the evaluation of the concepts of this work.

Chapter 3 focuses on the relevant information for collecting and presenting contextual information, its effects and impact on the learning interaction cycle, and mechanisms of controlling it. The core principle of the learning interaction cycle is the interaction of learners with their learning environment. Previous research highlights that such interaction is related to the experience and progress of learners. However, a conceptual gap between the learner actions within a learning environment and the responses that are provided to the learners is identified. To bridge this gap a layered model of context-aware systems that meets the requirements for supportive responses has been adopted. The model has four layers and describes the information processing of learners' interaction footprints in a learning environment: The sensor layer, the semantic layer, the control layer, and the indicator layer. This model has been applied to analyse the results that are reported in the literature. The chapter raises three main research questions for further research.

Indicators help actors to organise, orientate, and navigate through environments by providing contextual information that is relevant for performing learning tasks. Chapter 4 analyses the requirements, presenting a model and an initial prototype of a software system that uses smart indicators to support learners to be more engaged into the learning process. It is argued that indicators need adaptation as learners develop on their learning paths in order to support interactions throughout the learning process. The learning interaction cycle of self-regulated learning is used as a model for developing an architecture that supports the interaction between a learner and a learning environment. The technical feasibility of the architecture has been tested by an implementation that critically reflected the underlying technical and educational concepts for self-directed and incidental learning.

Part 2 has three chapters that cover three studies analysing interaction footprints and the effects of indicators on engagement and reflection of self-directed and self-organised learners. The chapters are: "visualisation of interaction footprints for engagement in online communities" (Chapter 5), "implications of writing, reading, and tagging on the web for reflection support of self-directed learning" (Chapter 6), and "a tag cloud for the reflective self-directed learner" (Chapter 7).

The majority of recent activities in contextualised and ubiquitous learning focus on mobile scenarios, with location as the primary contextual dimension for situated learning. However, the meaning of context aware learner support is not limited to location based solutions, as it is highlighted by the educational paradigms of situated learning and communities of practice. Chapter 5 analyses learner participation as a dimension for adapting graphical indicators for engaging and motivating learners in participating and contributing to an open community. The analysis is based on interaction data and interviews with participants in a nine weeks design study, during which the effect of two indicators on the engagement of the participants in the group activities has been compared. The trend of the results supports the presumption that the learners' perception of their activity visualisations is context dependent. The results suggest that more engaging visualisation also polarised the participants in a group of scientific knowledge workers. While contributing participants were attracted to contribute more to the community, non-contributing participants described the same visualisation as distracting.

The use of tags as user generated meta-data on the web as well as the visualisation of tags in tag clouds has recently received a lot of attention in research and practice. Tag clouds are a popular and simple visualisation of the usage of free form keywords (tags) on the Internet. The main focus of the related work lies on indexing and accessing content for learning, but not how tags and tag clouds can be used for supporting the actual learning process.

Chapter 6 focuses on supporting reflection of learners by using different presentation approaches of user generated meta-data for reflection support. Previous research has suggested that implicit interest expression can be a valuable source for reflection support. Visualising implicit or "tacit" interest in tag clouds could help learners to understand the connections of their content-related activities to the tags that are assigned to the content. For grounding this potential in the social practice of using tags in teams and small communities, over three months the tagging habits of a small community has been observed. This study focused on the social practices of using tags explicitly and implicitly. This chapter analyses these observations with regard to social navigation of teams and small communities, relations of implicit and explicit interest in tags, and usages of tags on different participation levels. The findings on these dimensions of the social practice of using and sharing tags in groups help to develop a better view on the requirements of providing reflection support.

Chapter 7 reports on a qualitative study of the application of tag clouds to support meta-cognition in self-directed and incidental learning. The study in chapter 7 analyses the use of the ReScope system that provides a personal tag cloud visualisation of the tags that are used with the personal bookmarks of a learner in a public social bookmarking service. ReScope is based on a reflection support use case developed by the TENCompetence project. The study focuses at the types of meta-cognitive control based on reflection notes of the learners. These notes were analysed regarding the content of the reflections as well as regarding their meta-cognitive type. The study has two outcomes. Firstly, a personal tag cloud can stimulate reflection on the tagging activity of a learner. Secondly, reflecting on the tagging activity is not built into the design of a tag cloud.

The general discussion in Chapter 8 links the two parts of this thesis on the grounds of the three key questions that were raised in the conclusion of Chapter 3. The findings indicate that it is possible to develop and provide targeted solutions for supporting self-directed, self-organised and incidental learning. The results suggest that the data from underlying sensors themselves are not providing contextual information for a learner, but that it is a result of aggregation of the data. Such aggregations can be designed according to the dimensions and factors of the context framework that has been defined in the first part of the thesis. Therefore, solutions that use interaction footprints can be designed independently from pre-structured domain knowledge or educational designs. This opens opportunities for developing new forms of supporting self-directed and incidental learning in learner controlled environments.

Samenvatting

In deze dissertatie wordt de rol van context op het ondersteunen van zelfgestuurde en zelforganiserende leerlingen op het web geanalyseerd. Het doel van het gerelateerde project was het ontwikkelen van nieuwe benaderingen om terugkoppeling te geven op leeracties in kennisdomeinen en sociale omgevingen die niet vooraf gestructureerd waren voor instructie. Met dit doel voor ogen werden simpele visualisaties van leeractiviteiten (zogenaamde indicatoren) toegevoegd aan, op het web gebaseerde, informatie systemen. De onderzoeksvraag van deze dissertatie is of de perceptie van deze indicatoren contextgerelateerd is.

Deze dissertatie rapporteert over een verkennend onderzoeksontwerp en bestaat uit twee delen. Het eerste deel beschrijft het theoretische en conceptuele onderzoek. In het tweede deel wordt het effect van indicatoren onderzocht in experimentele systeemimplementaties.

Deel I heeft drie hoofdstukken: "three pillars for research" (hoofdstuk 2), "smart indicators to support the learning interaction cycle" (hoofdstuk 3) en "smart indicators of learning interactions" (hoofdstuk 4).

In hoofdstuk 2 wordt de theoretische achtergrond van deze dissertatie beschreven. Het hoofdstuk begint met het situeren van het onderzoek in de grotere context van de levenslange competentieontwikkeling en het leren in de professies. Binnen dit terrein wordt de focus op zelfgestuurd en incidenteel leren gecontrasteerd met andere typen van onderwijs en leren. Voortbouwend op deze fundering wordt in het hoofdstuk verder ingegaan op de drie theoretische pilaren voor dit onderzoek: gesitueerd leren, feedback en informatievisualisatie. Deze pilaren zetten het werk in deze dissertatie in context en geven een conceptueel kader dat gebruikt is voor het ontwikkelen van het systeem en de evaluatie van concepten.

In hoofdstuk 3 ligt de nadruk op de informatie die relevant is voor het verzamelen en aanbieden van contextuele informatie, de invloed hiervan op de leerinteractiecyclus en de mechanismen om het te sturen. Het kernprincipe van de leerinteractiecyclus is dat leerlingen interageren met hun leeromgeving. Eerder onderzoek liet zien dat een dergelijke interactie belangrijk is voor de ervaring en vooruitgang van de leerling. Echter, er is een conceptuele kloof geïdentificeerd tussen de acties van de leerling binnen de leeromgeving en de terugkoppeling die aan de leerlingen wordt gegeven. Om deze kloof te overbruggen is een gelaagd model van contextbewuste systemen toegepast dat voldoet aan de benodigdheden voor ondersteunde repliek. Dit model heeft vier lagen en beschrijft de informatieverwerkingen van leerlingen in de leeromgeving: de sensorische laag, de semantische laag, de controlelaag en de indicatorlaag. Dit model werd toegepast om de resultaten in de literatuur te analyseren. Het hoofdstuk roept drie hoofdvragen op voor verder onderzoek.

Indicatoren helpen de actoren bij het organiseren van, oriënteren in en navigeren door een omgeving met ondersteuning van contextuele informatie die relevant is bij het uitvoeren van leertaken. In hoofdstuk 4 wordt een analyse gemaakt van de voorwaarden, een model en een initieel prototype. Dit prototype is in de vorm van een sofware systeem dat slimme indicatoren gebruikt om leerlingen te ondersteunen en meer te betrekken bij hun leerproces. Bepleit wordt dat deze indicatoren adaptief moeten zijn om de interacties gedurende het leerproces te blijven ondersteunen. Dit omdat leerlingen hun eigen leerpaden ontwikkelen. De leerinteractiecyclus van zelfgestuurd leren wordt gebruikt als model voor het ontwikkelen van een architectuur die de interactie tussen leerling en leeromgeving ondersteunt. De technische haalbaarheid van deze architectuur werd getest aan de hand van een implementatie die kritisch reflecteerde op de onderliggende technische en educatieve concepten van zelfgestuurd en incidenteel leren.

Deel 2 heeft drie hoofdstukken in welke studies worden beschreven die de interactiesporen alsmede de effecten van indicatoren op de betrokkenheid en reflectie van zelfgestuurde en zelforganiserende leerlingen onderzoeken. De hoofdstukken zijn 'visualisation of interaction footprints for engagement in online communities' (hoofdstuk 5), 'implications of writing, reading, and tagging on the web for reflection support of self-directed learning' (hoofdstuk 6) en 'a tag cloud for the reflective self-directed learner' (hoofdstuk 7).

Het merendeel van de meer recente activiteiten in contextgerelateerd en ubiquitair leren spitsen zich toe op het mobiele scenario met 'locatie' als de primaire contextuele dimensie voor gesitueerd leren. Echter, de betekenis van ondersteuning voor contextbewust leren is niet beperkt tot oplossingen die zich toeleggen op locatie, zoals het nu naar voren wordt gebracht in onderwijsparadigma's van gesitueerd leren en 'communities of practice'. In hoofdstuk 5 wordt de participatie van leerlingen als een dimensie voor adaptieve grafische indicatoren van interactiedata geanalyseerd met als doel om de deelnemers van een 'open community' te engaren en te motiveren om deel te nemen aan deze community. De analyse is gebaseerd op interactiedata en interviews met deelnemers in een negen weken durende design studie, gedurende welke de effecten werden vergeleken van twee indicatoren op de betrokkenheid van de deelnemers in groepsactiviteiten. De resultaten laten een trend zien welke de assumptie ondersteund dat de percepties van leerlingen in de visualisaties van activiteiten afhankelijk zijn van de context. Bevindingen laten zien dat een meer aantrekkelijke visualisatie er ook voor zorgde dat er een polarisatie ontstond voor de deelnemers in deze groep: hoewel deelnemers aangespoord werden meer bij te dragen aan de gemeenschap, werden deelnemers die niet veel bij droegen afgeleid door dezelfde visualisaties.

Het gebruik van 'tags' als door gebruikers gegenereerde metadata op het web, alsmede de visualisaties van deze tags in 'tag-wolken' heeft de laatste tijd veel aandacht gekregen in zowel onderzoek als praktijk. De nadruk ligt bij dit werk op de indexering en toegankelijkheid van de leerstof, maar niet hoe deze tags gebruikt kunnen worden in het ondersteunen van het leerproces.

Hoofdstuk 6 legt zich toe op het onderzoeken van de ondersteuning van reflectie bij leerlingen door gebruik te maken van verschillende presentatiebenaderingen voor de metadata, gegenereerd door gebruikers. Eerder onderzoek heeft laten zien dat de expressie van impliciete interesse een waardevolle bron kan zijn voor de ondersteuning van reflectie. Het visualiseren van impliciete interesse in tag-wolken kan leerlingen mogelijk helpen de connecties tussen hun inhoudgerelateerde activiteiten en de tags die aan die inhoud worden gehangen beter te begrijpen. Om dit potentieel voor het sociale gebruik van tags in kleine teams of gemeenschappen te ondersteunen, werd een drie maanden durend experiment uitgevoerd. Dit experiment verkende het expliciete en impliciete sociale gebruik van tags. Dit hoofdstuk analyseert de data van dit experiment met betrekking tot sociale navigatie van teams of kleine gemeenschappen, relaties in expliciete of impliciete interesse in tags en het gebruik van tags op verschillende niveaus van deelname. De bevindingen van deze dimensies van sociale praktijken in het gebruiken en delen van tags in groepen helpen bij het vormen van een beter begrip van de vereisten voor het aanbieden van ondersteuning voor reflectie.

In hoofdstuk 7 wordt een kwalitatieve studie gerapporteerd die ingaat op de toepassing van 'tag-wolken' als ondersteuning voor metacognitie in zelfgestuurd en incidenteel leren. Tag-wolken zijn een populair en simpele visualisatie van het gebruik van losse sleutelwoorden op het internet. In de studie in hoofdstuk 7 wordt een analyse gedaan met behulp van het ReScope systeem dat een persoonlijke tag-wolk weergeeft van die tags, die gebruikt worden in een publieke sociale 'bookmarking service'. ReScope is gebaseerd op een casus in het gebruik van reflectieondersteuning ontwikkeld binnen het TENCompetence project. De studie legt zich toe op de typen van metacognitieve controle gebaseerd op reflectieaantekeningen van leerlingen. Deze aantekeningen werden geanalyseerd op de inhoud wat betreft reflecties alsmede wat betreft het metacognitieve type. De studie heeft twee belangrijke bevindingen. Ten eerste kan een persoonlijke tag-wolk de tag-activiteit van de leerling bevorderen. Ten tweede is het reflecteren op de tag-activiteit niet in het ontwerp van de tag-wolk gebouwd.

De algemene discussie in hoofdstuk 8 verbindt de twee delen van deze dissertatie en beantwoordt de drie kernvragen die naar voren werden gebracht in hoofdstuk 3. De bevindingen laten zien dat het mogelijk is om gerichte oplossingen te ontwikkelen en verzorgen voor het ondersteunen van zelfgestuurd, zelforganiserend en incidenteel leren. Het resultaat suggereert dat de data van de onderliggende sensoren niet zozeer zelf de contextuele informatie verschaffen aan de leerling, maar dat dit een resultaat is van de aggregatie van dergelijke data. Dergelijke aggregaties kan ontwikkeld worden aan de hand van de dimensies en factoren van het contextuele raamwerk dat in het eerste deel van deze dissertatie werd beschreven. Oplossingen die gebruik maken van de interactiesporen kunnen daarom onafhankelijk van voorgestructureerde domeinkennis of onderwijsontwerpen ontwikkeld worden. Dit opent mogelijkheden voor het ontwikkelen van nieuwe vormen voor het ondersteunen van zelfgestuurd en incidenteel leren in leerling-gestuurde omgevingen.

Curriculum Vitae

Christian Glahn, born on 20th June 1972 in Berlin, Germany, has a long standing affinity to applied technical developments in the educational field. This already manifested in the development of a simple vocabulary trainer on the C64 in 1987. Later he studied educational and computer science, which he started at the Freie Universität Berlin. Early his interests in education focused on adult learning, community education, and educational philosophy. After finishing his studies in computer science, Christian moved to the University of Innsbruck in order to concentrate his studies on media education, particularly computer supported learning in order to link his competences in computer science with education. He achieved this goal with his master thesis on the analysis of the modelling of educational practice using the Educational Modelling Language (EML), which also brought him into contact with OUNL.

His professional development started in 1998 while working in developing e-commerce and interactive customer relationship services for different enterprises in Germany and in Greece. In 2000 his professional focus linked the research interests for the first time while being the technical lead in Austria's first campus-wide installation of a virtual learning environment (VLE) at the University of Innsbruck. This work brought him first into contact with active open source software development and from 2001 onwards he started contributing frequently to the community, most remarkably by developing and maintaining XML bindings for the Perl programming language, which now have become part of most major POSIX based operation systems, including Linux, MacOSX, and Solaris. However, Christian's professional interests were focused in research and development at the intersection of technology and education. He worked in the fields of mobile informal learning and applied standards of educational technologies at Seibersdorf research, Austrian Research Centers. Later he focused on non-formal learning and lifelong learning at the University of Innsbruck and contributed to the development of the European Knowledge Centre on Youth Policy of the European Commission and the Council of Europe.

In 2006 Christian joined the team of the Open University of the Netherlands in order to work on his Ph.D. and to participate in the TENCompetence project. In this project he contributed in the requirements engineering, the evaluation of the project results, and the organisation of international training events. Christian is also involved into other European research projects such as the GRAPPLE project and the STELLAR Network of Excellence.

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